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TECHNICAL DESCRIPTION OF THE RAPID ANALOGUE SELECTION SYSTEM INCLUDING REGIONALIZED CAPABILITIES APPLIED TO THE MEDITERRANEAN SEA

(9) Final rept.

by

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A method is described for bit-coding meteorological analyses in terms of specifying parameters which measure pattern characteristics. By matching the bit-string produced for each analysis, an absolute measure of the similarity between any two meteorological situations can be obtained. An extension of the bit-coding methodology allows the development-in-time of two meteorological episodes to be compared. From these measures of similarity analogues can rapidly be selected from the data base.

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1. INTRODUCTION

The initial involvement of Meteorology International Incorporated with analogue prediction techniques developed out of years of association with the FNWC Optimum Track Ship Routing (OTSR) System. During this association it became apparent that the quality and timeliness of the product, based in part on analogue techniques, left much to be desired from the point of view of operational utility. Existing analogue selection and compilation techniques were crude and, in terms of computer processing time, were cumbersome and costly.

Confronted with this situation, MII became directly involved in analogue research and development as from January 1973 with the objective of devising and implementing an analogue selection scheme which was both rapid and based on comprehensive and realistic selection criteria. As the system was developed and its early capabilities explored, it became apparent that analogue selection based on the total hemisphere could only be useful in the broadest terms because of the great variability in synoptic patterns occurring simultaneously over the hemisphere. (The data base required to provide a reasonable number of good analogues if trying to match the hemisphere as a whole is far greater than that available.) Because of this variability, even the top-scoring hemispheric analogues had little relevance to any operationally-significant analogue forecast for a local area such as the Mediterranean Sea. What was required, of course, was the ability to focus on any pre-selected region, taking into account, when selecting analogues, only those essential features of the space and time scales of the atmospheric disturbances likely to affect the region during the objective period of the forecast.

The first efforts aimed at regionalizing the analogue selection system were carried out on behalf of NEPRF for the Mediterranean region;

subsequently, further work was performed for FNWC directed toward the eventual goal of a multi-regional capability.

These first efforts laid only the foundations of the Regionalized Rapid Analogue Selection System (RASS); further development work was required. This requirement was recognized and in June 1976, under NEPRF sponsorship, MII was awarded Contract No. N00228-76-C-3189 to continue with the development of RASS with specific emphasis on its application to the Mediterranean. Under the terms of this Contract, the work was to be carried out by the performance of Tasks 1 and 2, the objectives of these Tasks being detailed in Section 2. Task 1 was finished in December 1976, an Interim Report being delivered to NEPRF on completion. Task 2 has now been completed, and this Final Report presents the methods developed and the results obtained in fulfillment of both Task 1 and Task 2.

2. OBJECTIVES

The overall purpose of this project was to improve the regionalized rapid analogue selection capabilities with emphasis in the Mediterranean area. The specific objectives of the work were essentially as follows:

2.1 Task 1

a. Re-examine and modify the components presently used in the regionalized rapid analogue selection scheme.

b. Design an optimum storage configuration and construct a new history data base to incorporate necessary data resolution while significantly reducing total data tape handling in the current data base of 28 years.

c. Compute a climatology of each component field in addition to the history base.

d. Develop techniques which provide effective measurement of both large- and small-scale characteristics in both space and time of the component fields.

e. Design selection techniques so as to be pertinent for analogues covering the Mediterranean region, but with capabilities to be modified for any predetermined region in the Northern Hemisphere.

f. Produce an operational program to be run on the Fleet Numerical Weather Central (FNWC) CDC-6500 computer system.

g. Design methods for both tuning the regionalized rapid analogue scheme and for verification.

h. Write an interim report for the internal use of the Naval Environmental Prediction Research Facility.

2.2 Task 2

a. Expand upon the work initiated under Task 1 with increased tuning of the program.

b. Thoroughly demonstrate and evaluate at least two historical periods using data furnished by NEPRF.

c. Design a continuing program for verification statistics of the regionalized rapid analogue scheme.

d. Produce a final report to conform with MIL-STD-847A, Formal Requirements for Scientific and Technical Reports Prepared by or for the Department of Defense, 31 Jan 1973. The results of the demonstration and evaluation of the historical periods should be presented as case studies.

3. THE ANALOGUE APPROACH TO ENVIRONMENTAL FORECASTING

3.1 Terminology Used in This Report

A METEOROLOGICAL SITUATION, defined as occurring at a fixed point in time, may be represented and comprehended by an assemblage of SPECIFYING PARAMETERS.

A SCENARIO is a METEOROLOGICAL EPISODE or SEQUENCE, defined as a (normally brief) time-connected series of situations. The specifying parameters involve time.

A METEOROLOGICAL EVENT may be either a situation or a scenario, as defined above.

An ANALOGUE is a meteorological event selected from historical records as being acceptably similar (according to pre-established criteria involving the specifying parameters) to another event.

The BASEDAY is the meteorological event for which analogues are to be selected. For forecasting, either the current situation or the current scenario would be used. For hindcasting a baseday event would be chosen from historical records.

The ANALOGUE CANDIDATE is the particular event being compared with the baseday to assess its suitability for selection as an acceptable analogue.

MATCHING is the process of comparing the chosen baseday with all analogue candidates in order to select analogues. Matching is performed by comparison of corresponding specifying parameters.

The ANALOGUE SCORE is the number assigned to an analogue candidate as a result of the matching process, this number being a measure of the overall degree of matching or similarity.

PERSISTENCE FORECAST. A forecast method based on the assumption that meteorological conditions during the forecast period remain unchanged from those prevailing at the beginning of the forecast period. A persistence forecast may be taken as demonstrating zero skill, thus providing a basis for determining the effectiveness of other forecast techniques.

CLIMATOLOGICAL FORECAST. A forecast regarding the future value of a meteorological parameter, couched in terms which relate stated ranges of that parameter to their percentage probability of occurrence during the forecast period, based entirely on statistics.

DETERMINISTIC FORECAST. A forecast which gives only what is considered to be the most probable future value (or narrow range of values) of a meteorological parameter. In general no additional information is provided by which to assess the actual probability associated with the forecast, this assessment being left to the user--a process requiring considerable experience on the part of the user. A deterministic forecast is therefore an <u>incomplete</u> statement of available information.

PROBABILISTIC FORECAST. A forecast expressed in terms which distribute the full probability (100%) over the entire range of possible future values of a particular meteorological parameter. A probabilistic forecast is therefore a <u>complete</u> statement of available information.

3.2 Discussion and Outline of the Analogue Approach

3.2.1 General Approach

The analogue approach to meteorological forecasting is based on an ability to recognize significant degrees of similarity between events which have occurred in recorded meteorological history and the current event.

An historical event recognized as being an acceptably close match to the current event (or to another chosen historical event) is termed an "analogue". The underlying premise is that, given sufficient and relevant similarity, an analogy may be drawn between what did follow from the selected historical events, and what will follow from the current event.

Assuming this premise is accepted, it follows that any effective analogue forecasting system must include the following basic components:

a. A methodology for interpreting any meteorological event in terms of relevant specifying parameters.

b. A data base, expressed in terms of the specifying parameters, which is sufficiently large to encompass the range of significant variabilities which have occurred in meteorological history and which may possibly occur (within reason) during the forecast period.

c. A system for comparing the selected meteorological event with all others in the data base in order to select analogues. In practice of course, any practical scheme will find degrees of similarity ranging from very good matches (hopefully), to very poor matches. Thus the matching technique must incorporate a scoring system, allowing the analogue candidates to be ranked in order from the best fit to the worst fit.

d. A method of compiling a forecast from the selected analogues and their ensuing scenarios.

Note: As far as is known, no attempt has been made previously to select analogues based on a baseday scenario, only on a baseday situation. The ability to match scenarios, described in this Report, is a development unique to MII.

In essence the analogue approach is one of compiling a day-by-day "selective climatology"--the selection process eliminates those developments unlikely to ensue (based on meteorological history) from the current scenario or situation, choosing only those developments which, in the past, have evolved from events similar to those currently taking place. Clearly any skill used in selecting the appropriate developments and from them compiling a day-by-day "climatology", <u>must</u> provide a more skillful probabilistic forecast than using the complete climatology which incorporates <u>all</u> scenarios, including those recognizable as being unlikely to evolve from current events. If an analogue selection system fails to demonstrate this increase in skill then it follows that the design of the system is such that no skill is being used in the overall selection process.

As envisaged by MII, a major use of a successful analogue forecasting scheme lies in the compilation of extended range forecasts--say from 3 to 10 days. Out to 3 days the various numerical analysis and forecast models, aided by the subjective skills of the experienced forecaster, demonstrate considerable skill over persistence or climatology, this skill decreasing rapidly with lapsed time; after about 3 days any deterministic skill can only be expressed in gross terms. Although not displaying the initial skill available from numerical models, the probabilistic skill provided by an effective analogue system should degrade more slowly with time, providing more meaningful forecasts than numerical models after about 3 days. With current technology and understanding it seems unlikely that any <u>operationally</u> significant forecasting skill, superior to say a monthly climatology, can exist much beyond 10 days, although it may be possible to provide "trend" forecasts for longer periods.

Various analogue forecasting methodologies have been designed using the four basic components outlined above. Meaningful comparison of the effectiveness of these systems is made difficult, if not impossible, by the fact that the objective of each system usually differs from that of

other systems. However, none has demonstrated sufficient skill to warrant their sustained use in any operational context without further development.

3.2.2 The MII Approach

3.2.2.1 Regional Focus

Most weather elements of operational significance (e.g., winds, waves, clouds, precipitation, fog, etc.) are the result of synoptic-scale disturbances in space and time. On this scale the range of variabilities encountered on a hemispheric basis is so great that the available data base of meteorological history (30 years) is insufficient to provide analogues unless the selection criteria are made so coarse that synoptic-scale disturbances play little part in deciding analogue selection. As mentioned in Section 1, the alternative approach adopted by MII is to focus on a region, such as that determining the meteorological events affecting the Mediterranean Sea, making no attempt to match irrelevant external events. (It will be appreciated, of course, that to produce analogue forecasts for the Mediterranean Sea, a region considerably larger than the Mediterranean itself must be considered.)

3.2.2.2 The Available Historical Data Base

The MII system for analogue forecasting has been designed to exploit, on a regional focus basis, the information and resolution contained in the available history of synoptic fields. The available archived records consist of six component fields for the whole of the Northern Hemisphere for each date-time group. These are the three component-range-of-scale[1] (SV, SL and SD) fields for the 500-mb and 1000-mb height fields. An additional three thickness fields, one for each scale component, are produced from the 500-mb and 1000-mb isobaric fields as differences. Each of these nine fields is expressed by a 63x63 array of grid-point values oriented as shown

[1] See Appendix A.

in Fig. 1. The 30 years of available history with intervals of once daily and twice daily coverage is summarized as follows:

JAN 1946 - MAR 1955	once daily
APR 1955 - MAR 1960	twice daily
APR 1960 - DEC 1964	once daily
JAN 1965 - DEC 1975	twice daily

As discussed in Section 8.1.2, a more extensive data base is required to take full advantage of RASS--in particular, more frequent analyses are required to capture the small-scale (SD) variabilities of the atmosphere.

The gridded fields of this data base are not, of course, in the form required by RASS; one of the tasks (Task 1 b) of this Project was to construct a new history data base for use by RASS. (See Section 5.)

3.2.2.3 The Quick Screen

Any synoptic situation is represented by the appropriate set of 9 gridded fields discussed above. The fundamental component of any analogue selection scheme lies in the techniques used for representing the baseday and analogue candidate, thus allowing comparisons to be made and scored, and analogues selected. Various approaches can be used, all of which attempt to capture the essential pattern characteristics of the historical fields. Any approach should take into account the variations in resolution required by the different scales of atmospheric disturbance (i.e., SV, SL and SD). Also, the techniques used must be rapid enough to scan through the total history in an acceptable time without sacrificing (in the interests of speed) any of the necessary detail required for effective analogue selection.

In an attempt to speed up the selection process, an earlier version of the Rapid Analogue Selection System incorporated a preliminary "Quick Screen" process for producing a much-reduced list of potential analogue

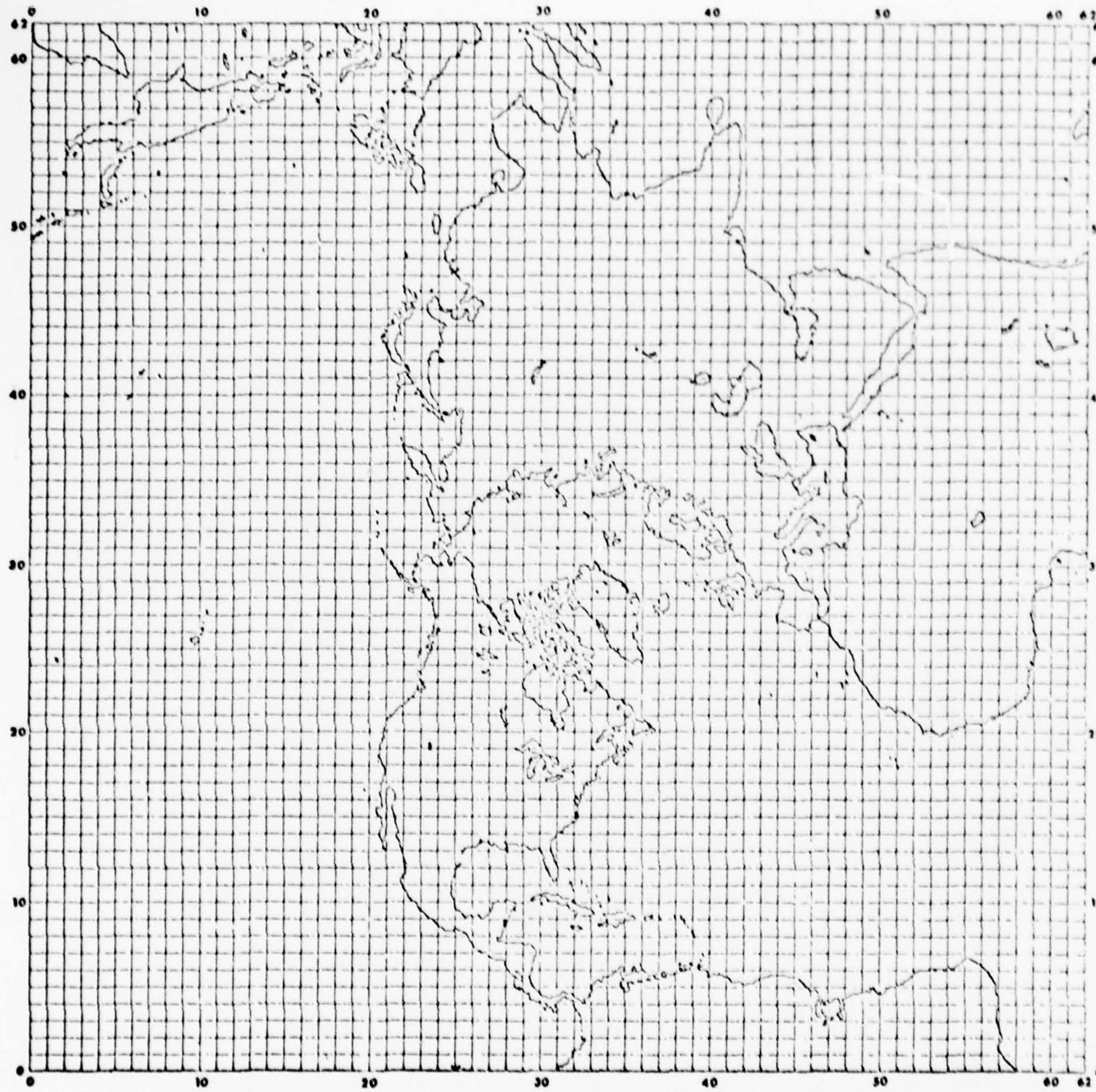

Fig. 1 The Standard 63x63 Grid Array of Northern-Hemisphere Coverage, Polar-Stereographic Projection. Note that the grid-point coordinates are numbered 0 through 62.

candidates. Having passed the Quick Screen criteria, these potential analogues were then assigned a final score using a functional measure which determined the proportion of baseday variance explained by each analogue candidate (Fig. 2a). The Quick Screen technique was based on a special bit-coding of component fields, designed so that the count of matching bits (baseday compared with analogue candidate) gave a measure of pattern similarity.

The Quick Screen was found to be so fast and effective at giving a preview of the final scores that it was realized it could be expanded in comprehensiveness to do the entire job of analogue selection. Quick Screen provides <u>absolute</u> measures of pattern similarity rather than the <u>relative</u> measures afforded by correlation coefficients or our functional measures. It can also give the regional distribution of pattern similarities for any component characteristics and degrees of resolution. The flexibility of the design readily allows analogue selections to be made on a regional-focus basis, utilizing data base subsets from the full hemispheric coverage.

Essentially, this particular component of the overall Rapid Analogue Selection System consists of an expanded, comprehensive, and very flexible Quick Screen process. If presented with current or other weather patterns (including scenarios), it can scan rapidly the data base and determine whatever similar weather patterns may have occurred in a history going back 30 years. The search, for an extensive region such as the Greater Mediterranean, can generally be accomplished in the order of three minutes of CDC-6500 CPU time; the complete history for the regionally focused subset can be accommodated on one large reel of magnetic tape. To satisfy Task 1 f of this Project, RASS has been designed, developed and optimized for operational use on the FNWC computer system. Program resource requirements are well within the constraints of operational specifications.

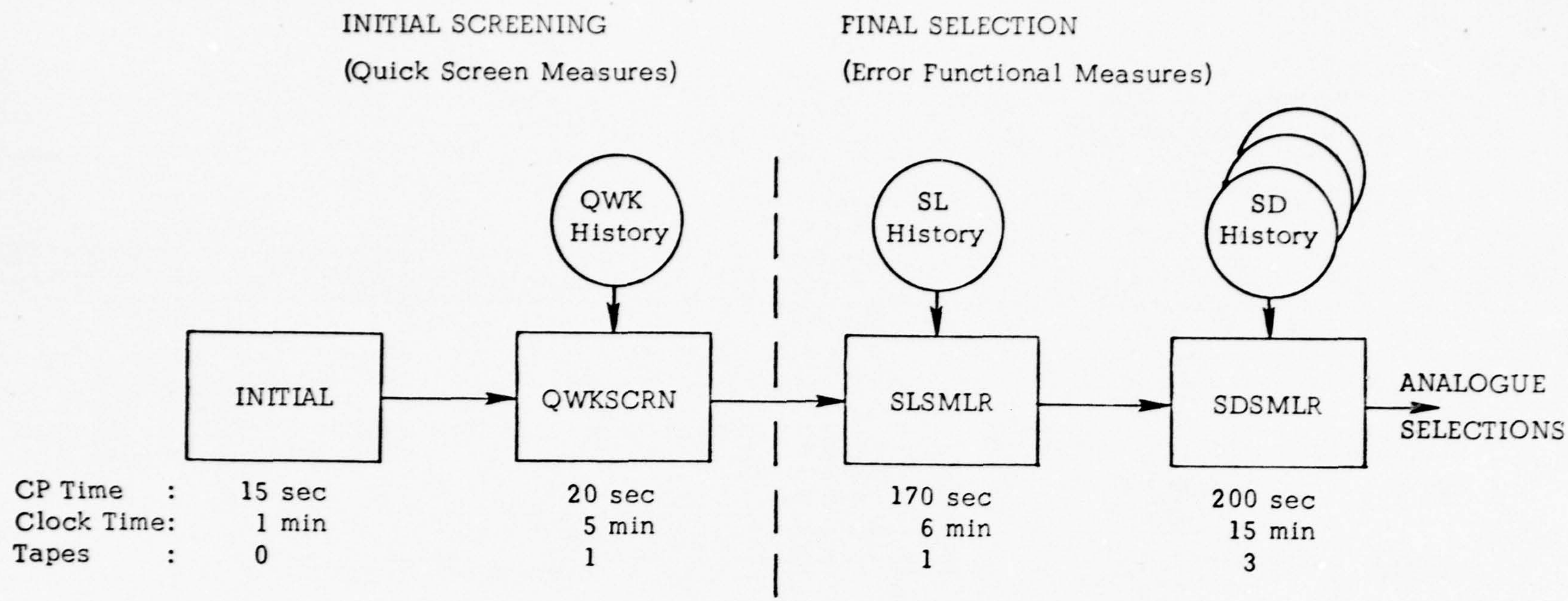

Fig. 2a Previous Rapid Analogue System

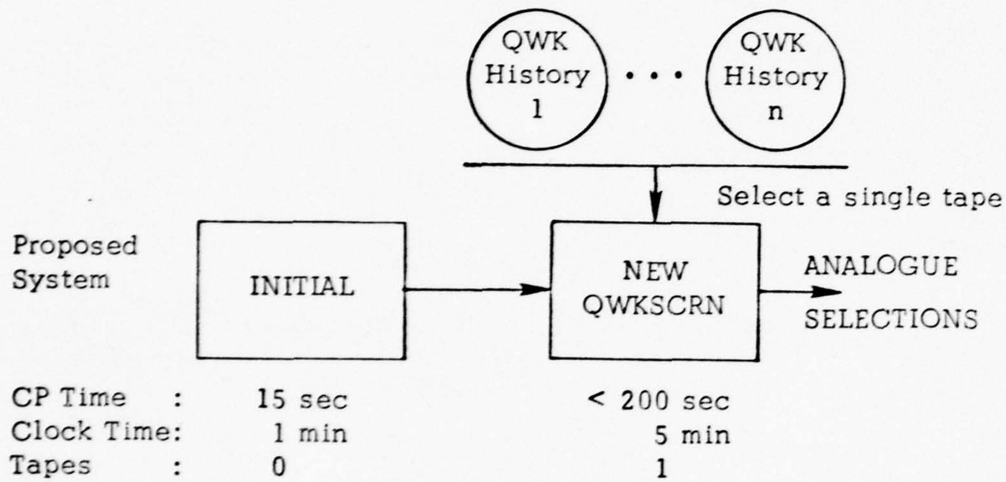

Fig. 2b Improved Rapid Analogue System

4. THE BASIC BIT CODE FOR REPRESENTING SYNOPTIC PATTERNS

4.1 Modular Design

The Quick-Screen bit code, applicable to gridded fields, is a scheme for coding synoptic patterns. The coded bit strings that are formed represent stratified grid-point values, and the differences between grid-point values, in regular spacings and orderings of repetition over the grid. The primary purpose of the code is to allow easy and rapid comparison of one field of patterns with another, measuring the degree of similarity between these two patterns in ranges of scale, in subregion by subregion, and in coarse, medium and fine degrees of resolution. The whole Northern Hemisphere can be covered at the full resolution of the code; however any subset may be extracted to correspond to a specified regional focus.

The bit code is formulated in terms of a modularization of the gridded fields, a module consisting of a 4x4 array of grid-point values. The spacing of the grid points used to form a module differs according to the range-of-scale inherent in synoptic patterns. Thus, in the Disturbance (SD) range-of-scale the full density of the 63x63 grid array is used; in the Long-wave (SL) range-of-scale a double-spaced subset is used; and in the Vortex (SV) range-of-scale a triple-spaced subset is used. These arrays are shown in Figs. 3, 4 and 5, respectively. The numbering of the modules extends the modular concept to arrays of 8x8.

In order to effect greater discrimination in the coding of the vortex (SV) range-of-scale field, the coding is applied to the anomaly of this field from a long-term (annual) mean field: $SV - \overline{SV}$. The north-south gradient of the vortex anomaly reverses between summer and winter, giving a strong seasonal discriminator. Other characteristics associated with eccentricities of the vortex are also accentuated.

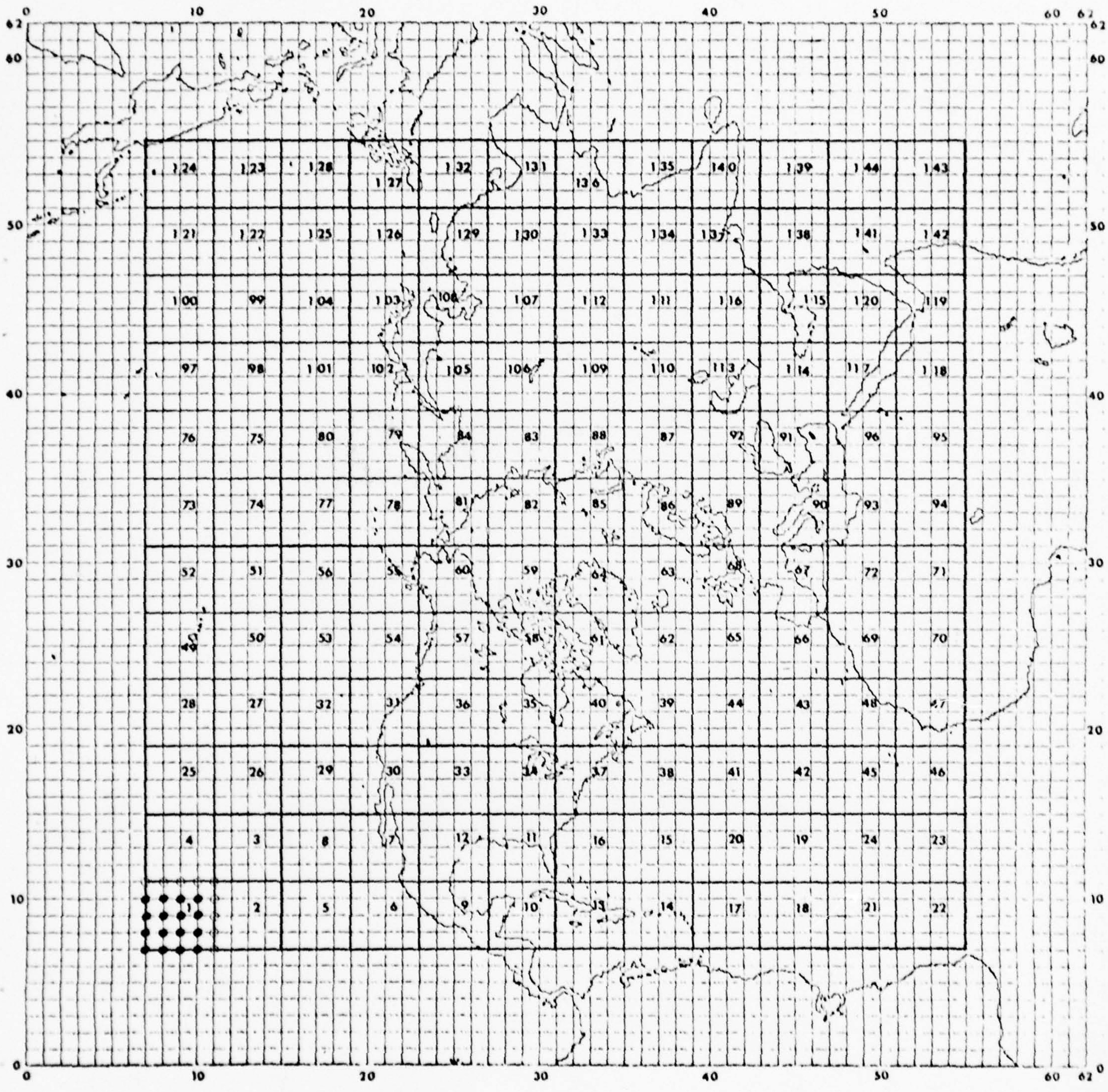

Fig. 3 Resolution and Coverage for the Disturbance Scale of Pattern Features--The SD Component Range-of-Scale. The 4x4 modules of the grid array are numbered for identification and ordering. The density of grid points used is illustrated in grid-array subset number 1.

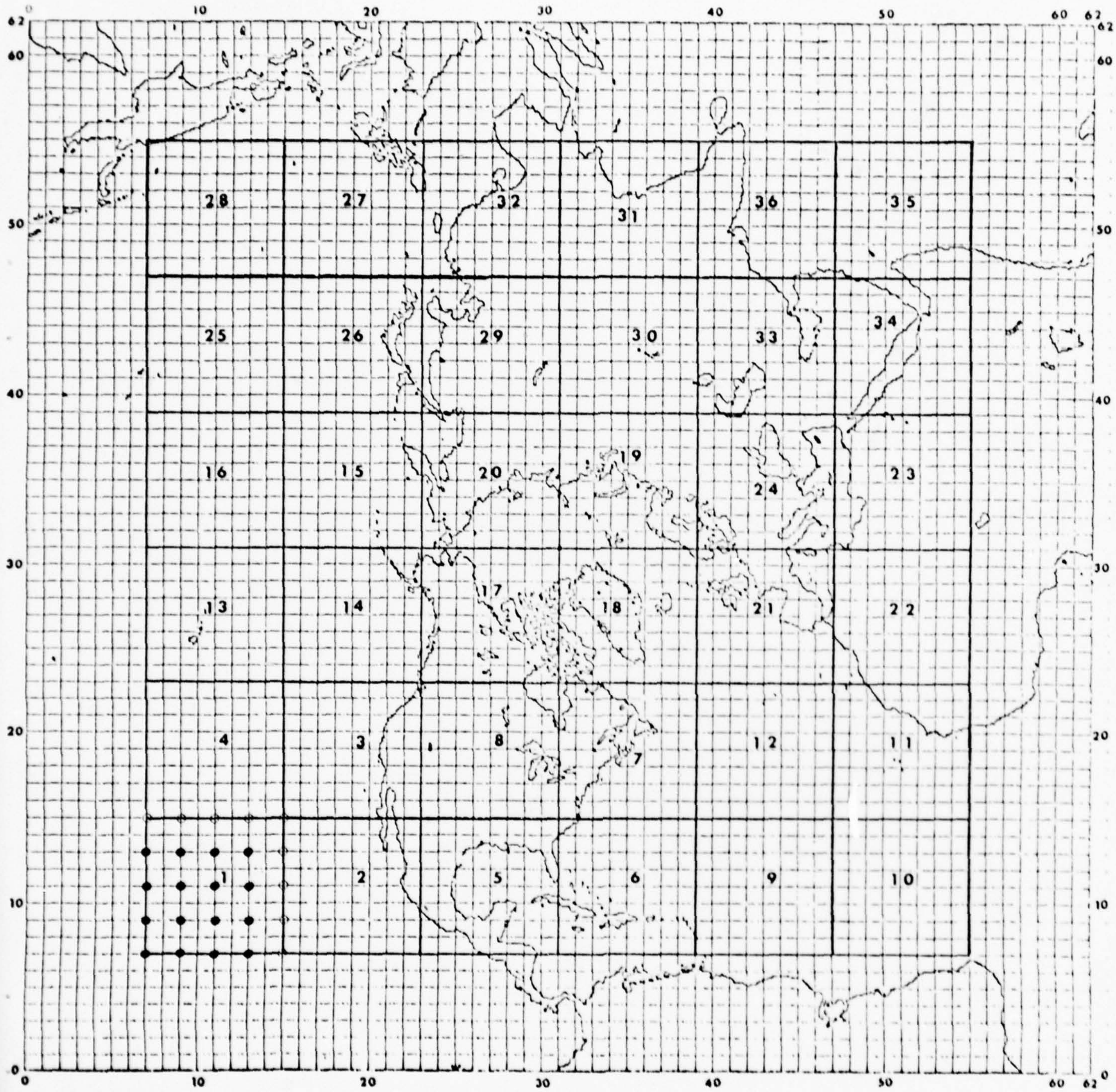

Fig. 4 Resolution and Coverage for the Large Scale of Pattern Features--The SL Component Range-of-Scale. The 4x4 modules of the grid array are numbered for identification and ordering. The density of grid points used is illustrated in grid-array subset number 1.

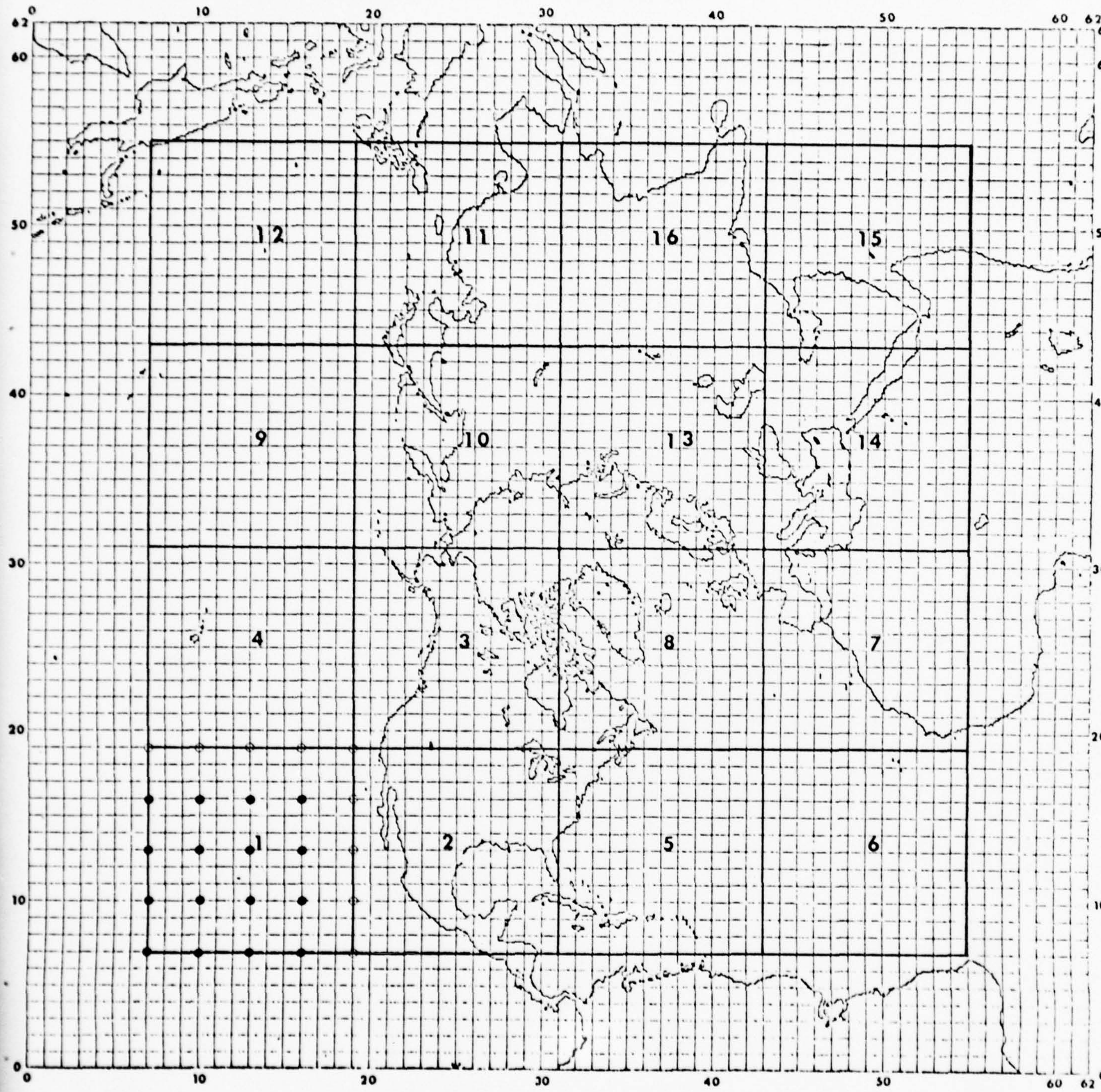

Fig. 5 Resolution and Coverage for the Planetary Vortex Scale of Pattern Features--The SV Component Range-of-Scale. The 4x4 modules of the grid array are numbered for identification and ordering. The density of grid points used is illustrated in grid-array subset number 1.

4.2 The Specifying Parameters for Each 4x4 Module

Associated with each 4x4 module of the total array there are seventeen parameters which measure the pattern characteristics (i.e., value and shape) of the height and thickness contours affecting that module for any given synoptic situation. This set of parameters has been designed to encompass the various scales of atmospheric disturbance and contour orientations that could occur in any meteorological situation. These seventeen parameters are shown in Fig. 6; note that each grid-point value of the 4x4 module enters into two of the seventeen parameters.

4.3 The Bit-Code for the Specifying Parameters

For any given meteorological situation, each of these seventeen parameters will have a numerical value of height or thickness (parameters A or B), or height or thickness difference (parameters C through Q). A bit-code is then assigned to each parameter, this bit-code defining the range interval into which the actual measured value of the parameter falls. (Note that this bit-code is not a binary code.) These range intervals are defined in terms of range levels which, in turn, are expressed in terms of a mean standard deviation, $\bar{\sigma}$ [1]. For example, Fig. 7 (page 22) shows the range intervals and range levels for parameter A, together with their specifying bit-codes (bit elements A1 through A7). The numerical values of the range levels are tabulated in Section 4.4.

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[1] More precisely, an RMS value in that the sample means were close to, but not exactly, zero.

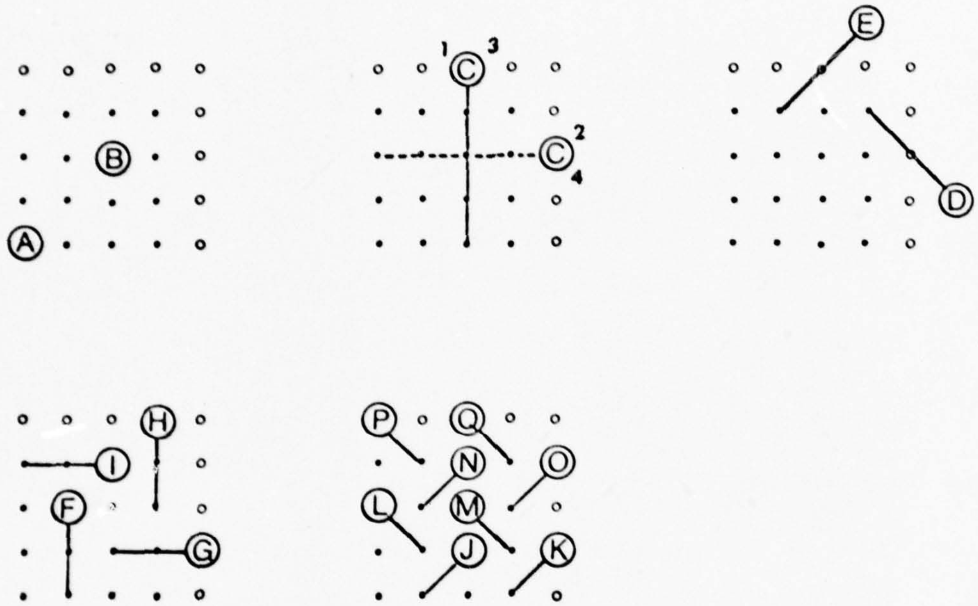


Fig. 6 The seventeen parameters which are bit coded for each 4x4 module of the grid array are shown in five subsets. A and B are actual parameter values at the two grid points indicated. The other parameters, C through Q, are differences. To calculate the value of any difference parameter, the value at the non-lettered end of the line segment is subtracted from the value at the lettered end. Parameter C alternates in orientation between even and odd numbered modules.

The range levels which define the range intervals are specified to the program which bit-codes the gridded fields. $\overline{\sigma}$ was calculated for each of the nine component fields based on a summer and winter sampling of each parameter. The samples were taken from all modules of the SD and SL component fields, but were confined to modules 3, 8, 10 and 13 of the three SV-anomaly component fields in order to accentuate the significant SV variabilities occurring in these modules compared with those of more southerly modules. The percentages, given as a normal expectance of occurrence for each range interval in Fig. 7, are based on an approximation to a normal distribution; they have not been verified by actually counting occurrences. However this is not critical because the distributions vary from season to season and from day to day. Values for the range levels for all seventeen parameters are given in Section 4.4.

Bit-codes are allotted to the other sixteen parameters in a manner similar to that described for parameter A. The bits assigned to all seventeen parameters are composed into a 60-bit word of code for that module. How this is done is described in detail in Section 4.5 but, basically, the composition of the word is so designed that the first quarter of the word gives a coarse resolution of a module pattern, the second quarter gives a medium resolution supplement, and the remaining half-word gives a fine resolution supplement. This composition provides a very flexible system. Thus portions of the full resolution words can be assembled to provide other resolutions; for example, a new word formed from the first quarters of a block of 4 words gives a coarse resolution coding of an 8x8 module. This flexibility for forming subsets of the basic bit code is exploited in regionally focusing the search for analogues.

In comparing two fields to determine their mutual degree of pattern similarity, the two sets of bit-coded words are simply matched, one with the other. The count of the number of corresponding bits that match is an absolute measure of the degree of pattern similarity between the fields

associated with each module. Extending this concept to include all modules representing the total field, it can be seen that this scheme can give a word-by-word (i.e., module-by-module) accounting of pattern similarity.

In Fig. 7 it will be noted that bit elements A6 and A7 (or B6 and B7 for parameter B) "flip" at the range levels corresponding to range intervals 9 and 10. This results in unwarranted bit matching when comparing corresponding pairs of these measures from two modular patterns. This will only occur when comparing the most mismatched pairs of measures--for example, if pattern x has parameter A in range interval 1 and pattern y has parameter A in range interval 10, then bit elements A6 and A7 will match. However, in such cases the entire module will generally score very low and this minor detraction is accepted in order to create extra range intervals without adding extra bits of coding.

Figure 7 shows the range intervals, range levels and bit coding for parameters A and B; Fig. 8 shows the associated scoring matrix, giving the number of matching bits obtained when two modules are compared. Note the effect (top-right and bottom-left corners of the scoring matrix) due to the spurious bit matching of elements A6 and A7 or B6 and B7. Figures 9 through 14 show similar tabulations for the other pattern-specifying parameters and their associated scoring matrices.

Range Levels	Range Intervals	Normal Expectancy of Occurrences	Bit Code Using Bit Elements Numbered						
			A1	A2	A3	A4	A5	A6	A7
	1	4.5%	0	0	0	0	0	0	0
1.700 $\bar{\sigma}$									
	2	8.0%	0	0	0	0	0	0	1
1.150 $\bar{\sigma}$									
	3	12.5%	0	0	0	0	0	1	1
0.675 $\bar{\sigma}$									
	4	12.5%	0	0	0	0	1	1	1
0.320 $\bar{\sigma}$									
	5	12.5%	0	0	0	1	1	1	1
0									
	6	12.5%	0	0	1	1	1	1	1
-0.320 $\bar{\sigma}$									
	7	12.5%	0	1	1	1	1	1	1
-0.675 $\bar{\sigma}$									
	8	12.5%	1	1	1	1	1	1	1
-1.150 $\bar{\sigma}$									
	9	8.0%	1	1	1	1	1	1	0
-1.700 $\bar{\sigma}$									
	10	4.5%	1	1	1	1	1	0	0

Fig. 7 Specification of Bit Code for Parameter A. The Bit Code for Parameter B is Similar.

	1	2	3	4	5	6	7	8	9	10
1	7	6	5	4	3	2	1	0	1	2
2	6	7	6	5	4	3	2	1	0	1
3	5	6	7	6	5	4	3	2	1	0
4	4	5	6	7	6	5	4	3	2	1
5	3	4	5	6	7	6	5	4	3	2
6	2	3	4	5	6	7	6	5	4	3
7	1	2	3	4	5	6	7	6	5	4
8	0	1	2	3	4	5	6	7	6	5
9	1	0	1	2	3	4	5	6	7	6
10	2	1	0	1	2	3	4	5	6	7

Fig. 8 The Scoring Matrix for Parameters A and B. Shown are the counts of the number of matching bits in comparing the bit code of range intervals.

Range Levels	Range Intervals	Normal Expectancy of Occurrences	Bit Code Using Bit Elements Numbered C1	C2	C3	C4
	1	10%	0	0	0	0
$1.280\ \overline{\sigma}$						
	2	15%	0	0	0	1
$0.675\ \overline{\sigma}$						
	3	25%	0	0	1	1
0						
	4	25%	0	1	1	1
$-0.675\ \overline{\sigma}$						
	5	15%	1	1	1	1
$-1.280\ \overline{\sigma}$						
	6	10%	1	1	1	0

Fig. 9 Specification of Bit Code for Parameter C. The Bit Codes for Parameters F, G, H and I are Similar.

	1	2	3	4	5	6
1	4	3	2	1	0	1
2	3	4	3	2	1	0
3	2	3	4	3	2	1
4	1	2	3	4	3	2
5	0	1	2	3	4	3
6	1	0	1	2	3	4

Fig. 10 The Scoring Matrix for Parameters C, F, G, H and I. Shown are the counts of the number of matching bits in comparing the bit code of range intervals.

Range Levels	Range Intervals	Normal Expectancy of Occurrences	Bit Code Using Bit Elements Numbered				
			D1	D2	D3	D4	D5
	1	5%	0	0	0	0	0
$1.650\ \overline{\sigma}$							
	2	10%	0	0	0	0	1
$1.040\ \overline{\sigma}$							
	3	15%	0	0	0	1	1
$0.525\ \overline{\sigma}$							
	4	20%	0	0	1	1	1
0							
	5	20%	0	1	1	1	1
$-0.525\ \overline{\sigma}$							
	6	15%	1	1	1	1	1
$-1.040\ \overline{\sigma}$							
	7	10%	1	1	1	1	0
$-1.650\ \overline{\sigma}$							
	8	5%	1	1	1	0	0

Fig. 11 Specification of Bit Code for Parameter D. The Bit Code for Parameter E is Similar.

	1	2	3	4	5	6	7	8
1	5	4	3	2	1	0	1	2
2	4	5	4	3	2	1	0	1
3	3	4	5	4	3	2	1	0
4	2	3	4	5	4	3	2	1
5	1	2	3	4	5	4	3	2
6	0	1	2	3	4	5	4	3
7	1	0	1	2	3	4	5	4
8	2	1	0	1	2	3	4	5

Fig. 12 The Scoring Matrix for Parameters D and E. Shown are the counts of the number of matching bits in comparing the bit code of range intervals.

Range Levels	Range Intervals	Normal Expectancy of Occurrences	Bit Code Using Bit Elements Numbered J1	J2
	1	20%	0	0
$0.84\ \bar{\sigma}$				
	2	30%	0	1
0				
	3	30%	1	0
$-0.84\ \bar{\sigma}$				
	4	20%	1	1

Fig. 13 Specification of Bit Code for Parameter J. The Bit Code for Parameters K through Q are Similar.

	1	2	3	4
1	2	1	0	1
2	1	2	1	0
3	0	1	2	1
4	1	0	1	2

Fig. 14 The Scoring Matrix for Parameters J through Q. Shown are the counts of the number of matching bits in comparing the bit code of range intervals.

4.4 Tabulation of Range Levels

As described in Section 4.3 the range levels are defined in terms of a mean standard deviation, $\overline{\sigma}$, calculated for each parameter by a sampling technique. The following tabulations show, for each of the nine component fields, the numerical values of the range levels for the seventeen pattern-specifying parameters.

Field: SV500 (all units in cm)

A, B:	7930	5365	3149	1493	0	-1493	-3149	-5365	-7930
C:			9847	5193	0	-5193	-9847		
D, E:		12550	7910	3993	0	-3993	-7910	-12550	
F, G, H, I:			6538	3448	0	-3448	-6538		
J-Q:				3195	0	-3195			

Field: SV1000

A, B:	7354	4975	2920	1384	0	-1384	-2920	-4975	-7354
C:			9860	5200	0	-5200	-9860		
D, E:		13875	8745	4415	0	-4415	-8745	-13875	
F, G, H, I:			6902	3640	0	-3640	-6902		
J-Q:				3531	0	-3531			

Field: SV5-10

A, B:	7480	5060	2970	1408	0	-1408	-2970	-5060	-7480
C:			9779	5157	0	-5157	-9779		
D, E:		12670	7986	4031	0	-4031	-7986	-12670	
F, G, H, I:			7709	4066	0	-4066	-7709		
J-Q:				3226	0	-3226			

Field: SL500

A,B:	12407	8393	4926	2335	0	-2335	-4926	-8393	-12407
C:			13810	7283	0	-7283	-13810		
D,E:		15650	9864	4980	0	-4980	-9864	-15650	
F,G,H,I:			9544	5033	0	-5033	-9544		
J-Q:				4783	0	-4783			

Field: SL1000

A,B:	5153	3486	2046	970	0	-970	-2046	-3486	-5153
C:			5828	3073	0	-3073	-5828		
D,E:		7178	4524	2284	0	-2284	-4524	-7178	
F,G,H,I:			4465	2354	0	-2354	-4465		
J-Q:				2243	0	-2243			

Field: SL5-10

A,B:	10977	7426	4358	2066	0	-2066	-4358	-7426	-10977
C:			11790	6217	0	-6217	-11790		
D,E:		13972	8807	4446	0	-4446	-8807	-13972	
F,G,H,I:			8225	4338	0	-4338	-8225		
J-Q:				4260	0	-4260			

Field: SD500

A,B:	7480	5060	2970	1408	0	-1408	-2970	-5060	-7480
C:			8018	4228	0	-4228	-8018		
D,E:		10058	6340	3200	0	-3200	-6340	-10058	
F,G,H,I:			5704	3008	0	-3008	-5704		
J-Q:				2520	0	-2520			

Field: SD1000

A,B:	4420	2990	1755	832	0	-832	-1755	-2990	-4420
C:			4851	2558	0	-2558	-4851		
D,E:		6115	3854	1946	0	-1946	-3854	-6115	
F,G,H,I:			3933	2074	0	-2074	-3933		
J-Q:				1680	0	-1680			

Field: SD5-10

A,B:	6630	4485	2632	1248	0	-1248	-2632	-4485	-6630
C:			7142	3766	0	-3766	-7142		
D,E:		8781	5535	2794	0	-2794	-5535	-8781	
F,G,H,I:			5394	2844	0	-2844	-5394		
J-Q:				2352	0	-2352			

4.5 Formation of the 60-Bit Word for a 4x4 Module

As outlined in Section 4.3 the bits allotted to the seventeen parameters of a module are composed into one 60-bit word of code for that module. The bit elements are arranged in such a way that, for any word, bits 1-15 give a coarse resolution of the module pattern, bits 16-30 give a medium resolution supplement and bits 31-60 give a fine resolution supplement. The following table shows the bit number location of each parameter element:

Bit Position in the 60-Bit Word	Parameter Element Located There	
1	A1	
2	A3	
3	A5	
4	B1	
5	B3	
6	B5	
7	C1	Bits 1-15 provide
8	C2	coarse pattern
9	C3	resolution
10	D2	
11	D4	
12	D5	
13	E2	
14	E4	
15	E5	
16	A6	
17	B6	
18	C4	
19	F1	
20	F2	
21	F3	
22	G1	Bits 16-30 provide
23	G2	a medium pattern
24	G3	resolution supplement
25	H1	
26	H2	
27	H3	
28	I1	
29	I2	
30	I3	

Bit Position in the 60-Bit Word	Parameter Element Located There	
31	A2	
32	A4	
33	A7	
34	B2	
35	B4	
36	B7	
37	D1	Bits 31-60 provide a fine pattern resolution supplement
38	D3	
39	E1	
40	E3	
41	F4	
42	G4	
43	H4	
44	I4	
45	J1	
46	J2	
47	K1	
48	K2	
49	L1	
50	L2	
51	M1	
52	M2	
53	N1	
54	N2	
55	O1	
56	O2	
57	P1	
58	P2	
59	Q1	
60	Q2	

It is instructive to follow the construction of a 60-bit word from the seventeen contributing parameters.

For any given parameter, say parameter A, there exists a "library" of ten 60-bit words, one for each of the ten range intervals associated with parameter A. The range interval is determined by progressive tests on the actual numerical measure of parameter A (see Section 4.4) and the appropriate word representing this range interval is selected from the library. For example, the library for parameter A is as follows:

Bit Positions:	1	2	3	4-15	16	17-30	31	32	33	34-60
Bit Elements :	A1	A3	A5		A6		A2	A4	A7	
<u>Range Interval</u>										
1	0	0	0	0-0	0	0-0	0	0	0	0-0
2	0	0	0	0-0	0	0-0	0	0	1	0-0
3	0	0	0	0-0	1	0-0	0	0	1	0-0
4	0	0	1	0-0	1	0-0	0	0	1	0-0
5	0	0	1	0-0	1	0-0	0	1	1	0-0
6	0	1	1	0-0	1	0-0	0	1	1	0-0
7	0	1	1	0-0	1	0-0	1	1	1	0-0
8	1	1	1	0-0	1	0-0	1	1	1	0-0
9	1	1	1	0-0	1	0-0	1	1	0	0-0
10	1	1	1	0-0	0	0-0	1	1	0	0-0

The above library should be compared with Fig. 7--note that the bit columns have been rearranged to separate A1, A3, A5 (coarse pattern

resolution), A6 (the medium resolution supplement), and A2, A4, A7 (the fine resolution supplement).

A similar process is followed for the remaining 16 parameters. The 60-bit word representing the module initially has all bits set to zero and is then formed by accrual of the 17 contributary 60-bit words representing the range intervals of the parameters. The total library contains 98 words, made up as follows:

A and B	10 each	total	20
C, F, G, H and I	6 each	total	30
D and E	8 each	total	16
J, K, L, M, N, O, P and Q	4 each	total	32
			98

Section 3.2.1 laid down the four basic components of any analogue forecasting scheme. It can be seen that the first of these--a methodology for interpreting any meteorological event in terms of relevant specifying parameters--is accomplished by the RASS techniques described in Section 4.

5. PRODUCTION OF THE BIT-CODED HISTORY

The second basic component of any analogue selection system (see Section 3.2.1) is the production of a data base in terms of the specifying parameters used to represent any meteorological events.

The source data set consists of about 150 large reel magnetic tapes and production of the bit-coded history was accomplished in two separate phases. The first step was to extract and/or generate the required nine component fields (see Section 3.2.2.2) from this source data set. Then these fields were processed into the full hemispheric bit code described in Section 4.

The coded data is organized on 8 large reel magnetic tapes and is the source for generation of any regional subset of the data.

6. REGIONAL FOCUS CAPABILITIES

This Section contains a description of the methods used for focusing on a selected region; the Greater Mediterranean will be used as an example. The techniques involved in searching for and selecting analogues (the third basic component of an analogue system--see Section 3.2.1) are described in Section 7.

6.1 General Approach

As described in Section 4.1 the bit-code is formulated in terms of a modularization of the gridded fields, a module consisting of a 4x4 array of grid-point values with the grid-point spacing being dependent on the 3 inherent ranges-of-scale.

On the SD range-of-scale the Northern Hemisphere is covered by 144 modules (see Fig. 3), the SL range-of-scale by 36 modules (see Fig. 4), and the SV range-of-scale by 16 modules (see Fig. 5). Each range-of-scale involves three fields (1000-mb, 500-mb, 500-1000-mb thickness) and thus a bit string of 588 words is required to represent the nine component fields of each synoptic situations; i.e., each date-time group in the bit-coded history.

Subsets of this coded history may be extracted to suit any purpose. A subset extracted for a specific region, such as the Greater Mediterranean, constitutes a "regional focus" subset of the data. As discussed in Sections 6.2 and 6.3, the required resolution should be taken into account when compiling a regional focus data base.

From the regional focus subset of the bit-coded history, specific date-time groups may be selected and combined to produce a bit-string

representing a regional focus scenario. Such a combination may be expressed by

$$SC_{(\tau-1) \rightarrow \tau} = S_{(\tau-1)} + S_{\tau}$$

where the scenario taking place from time $(\tau-1)$ to τ, $SC_{(\tau-1) \rightarrow (\tau)}$, is a combination of the situation S at $(\tau-1)$ and τ.

A search for analogues similar to the baseday scenario requires, of course, that analogue candidate scenarios and the baseday scenario, are both bit-coded in the same way; the similarity score between the baseday scenario and a particular analogue candidate scenario can then be based on a count of the matching bits.

The concept of scenario coding, matching, and analogue selection is discussed in greater detail in Section 7.

6.2 Standardized Approach

A standard procedure has been devised for specifying a regional focus and for extracting the required bit-coded data subset. This standard procedure allows a selected list of module numbers to be specified for each of the component fields, this list depending on the particular region of interest. (The reason for specifying module numbers for each component field is to provide greater realism and flexibility--the modules required for representation of one range-of-scale are not generally the same as for other ranges-of-scale.) The degree of resolution required for every listed module has also to be specified: for coarse resolution the first quarter of the bit-coded word for that module is extracted; for medium resolution the first half of the word is extracted; and for fine resolution the full word is

extracted. The resulting subset for each component field is rearranged into three groups of words:

a. Coarse-resolution words formed by stringing together all quarter-words which had resided in the upper quarter word before extraction;

b. Medium-resolution-supplement words formed by stringing together all quarter-words which had resided in the second quarter-word before extraction;

c. Fine-resolution-supplement words formed by stringing together all half-words which had resided in the second half of the word before extraction.

(Zeroes are used as necessary to complete the last word of each group so formed.)

6.3 The Greater Mediterranean Focus

The standardized approach outlined in Section 6.2 has been applied to the Greater Mediterranean region. The regional focus is specified by range-of-scale component fields and Figs. 15, 16 and 17 show the focus for the SD, SL and SV fields respectively. Extractions are made only for the modules where numbers have been circled. A double circle indicates fine resolution, a double bar under the number indicates medium resolution, and a single bar indicates coarse resolution for that module.

To construct the specification list (see Section 6.2) only the lowest module number of each group of four modules is listed; e.g., specifying module number 37 automatically incorporates modules 37 through 40. Following a module number a code is used to specify the resolution required for each of the four associated modules in numerical order. The resolution

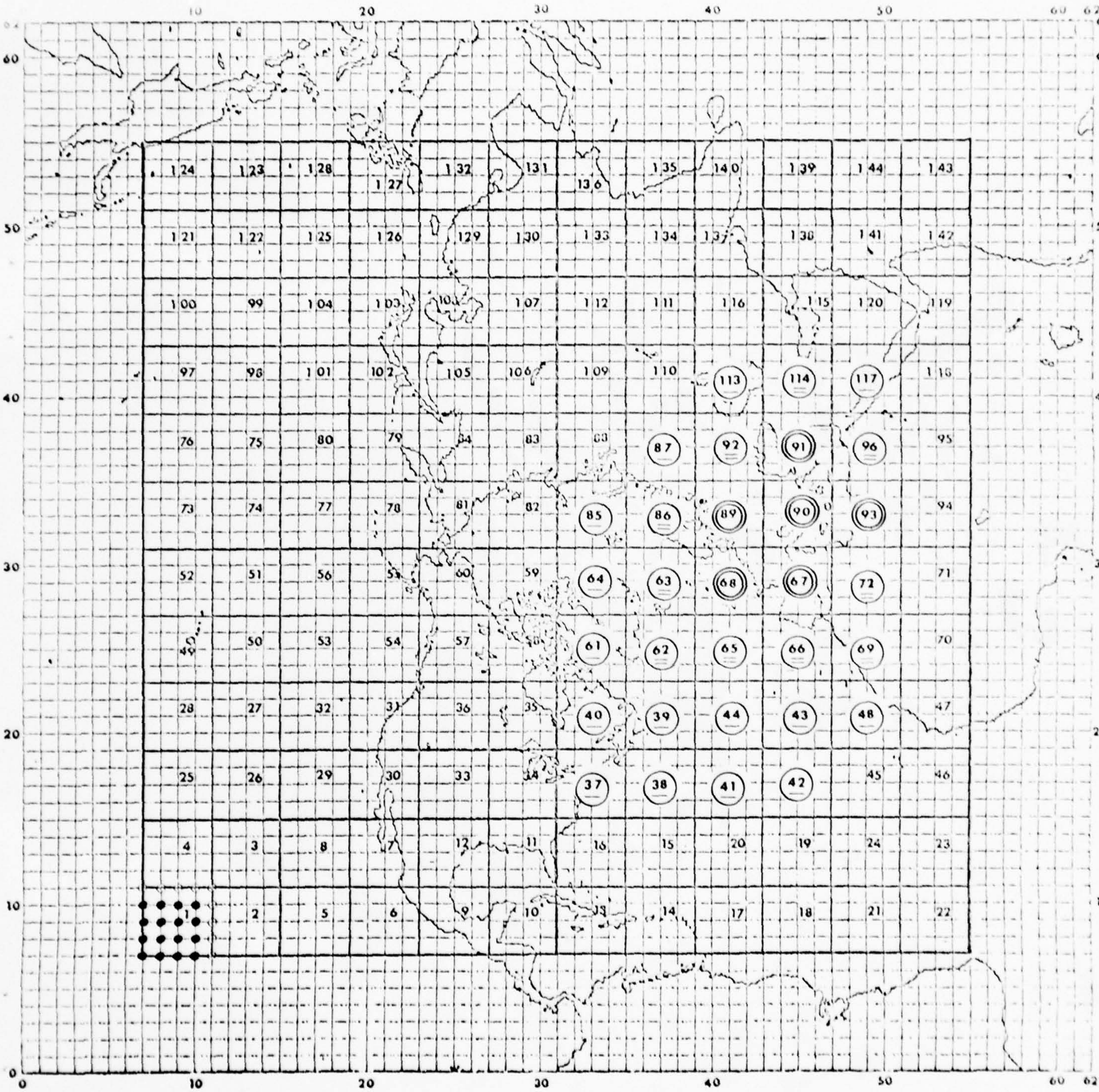


Fig. 15 Greater-Mediterranean Focus for the SD Component Fields. Extractions are made only for the circled-number modules. A double circle indicates fine resolution. A double bar under the number indicates medium resolution. And a single bar under the number indicates coarse resolution for that module.

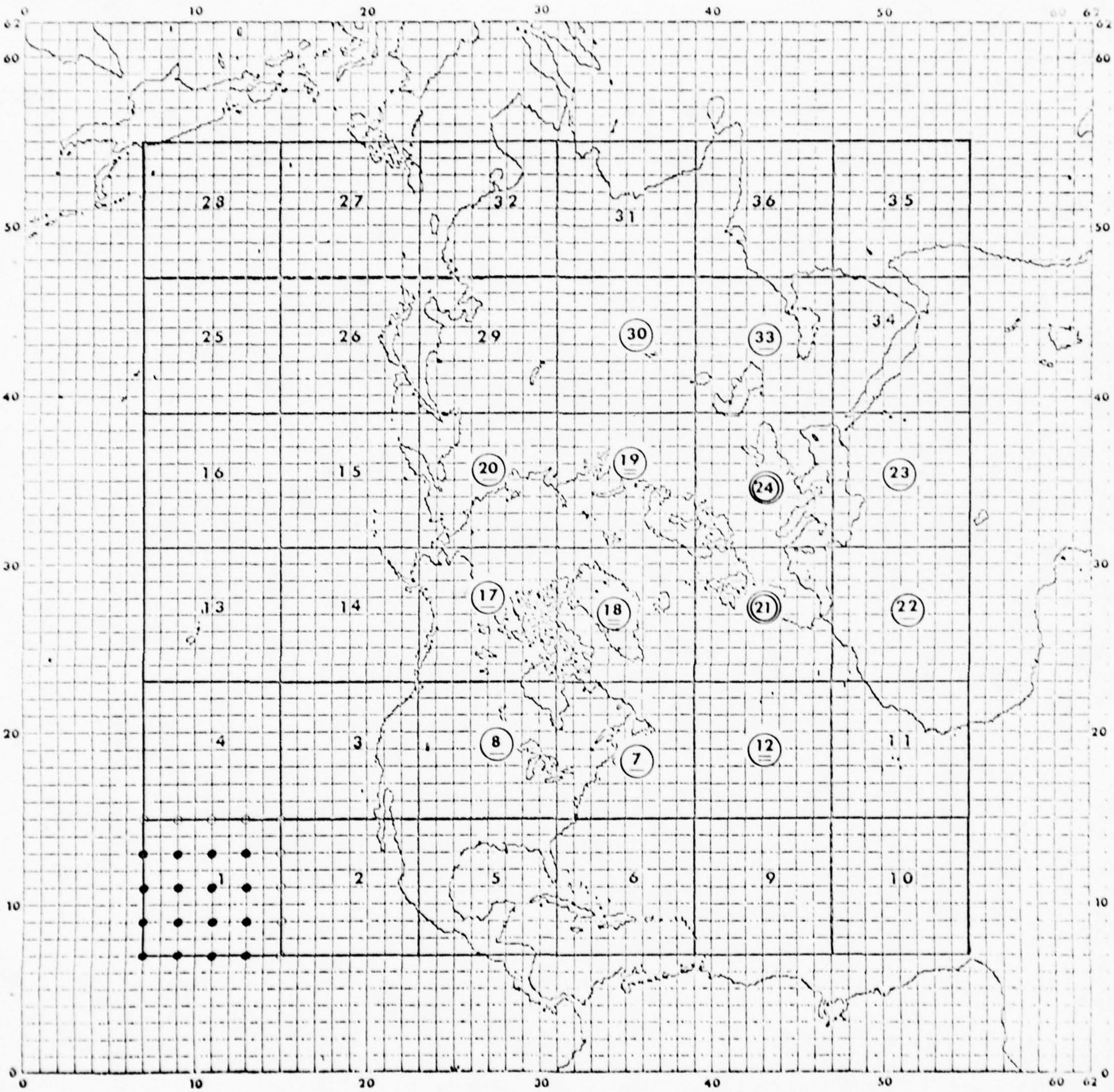


Fig. 16 Greater-Mediterranean Focus for the SL Component Fields. Extractions are made only for the circled-number modules. A double circle indicates fine resolution. A double bar under the number indicates medium resolution. And a single bar under the number indicates coarse resolution for that module.

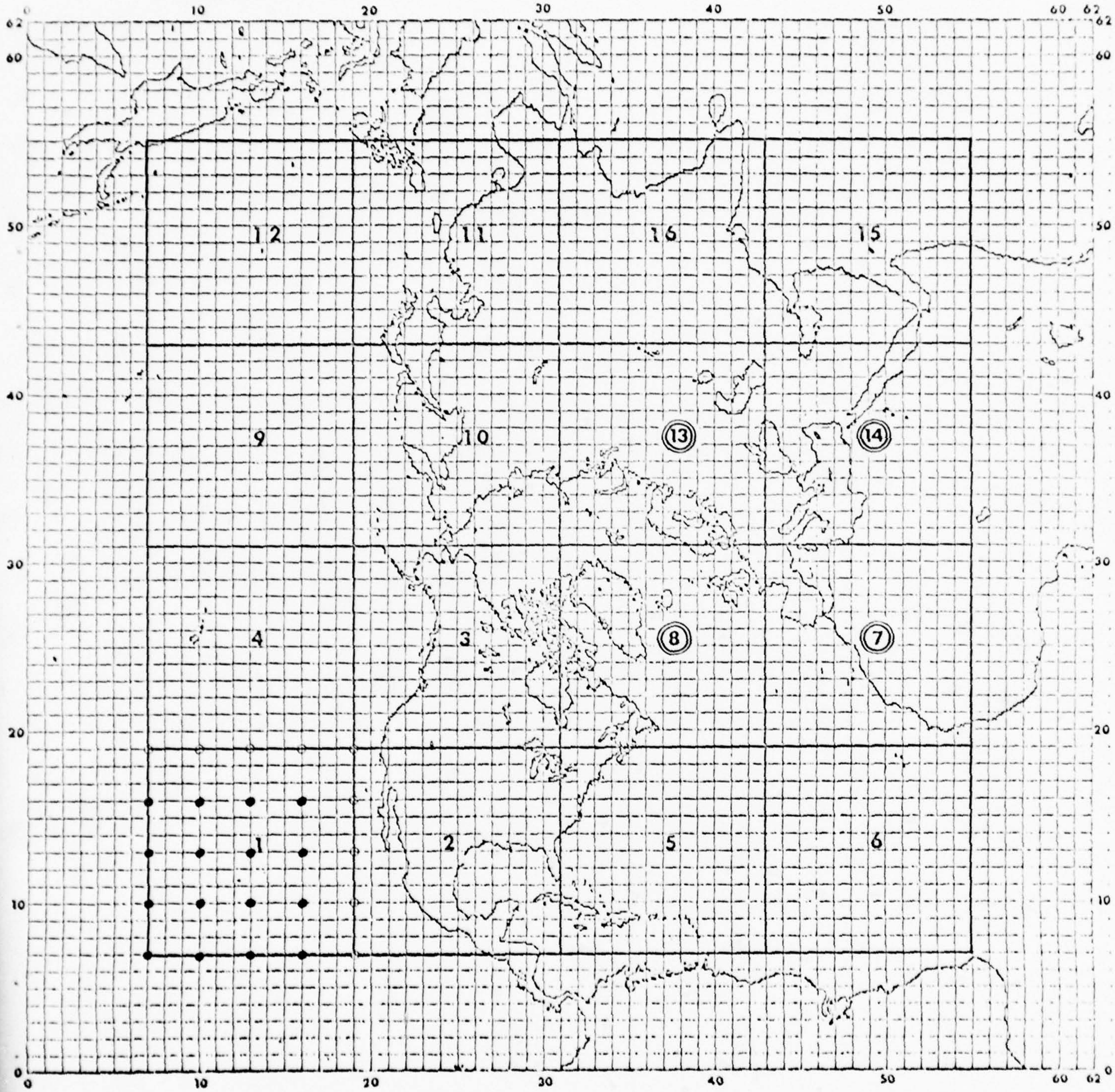


Fig. 17 Greater-Mediterranean Focus for the SV Component Fields. Extractions are made only for the circled-number modules. A double circle indicates fine resolution. A double bar under the number indicates medium resolution. And a single bar under the number indicates coarse resolution for that module.

code is 1 for coarse, 2 for medium, and 4 for fine resolution. Thus, for example, a specification list element given as 65:2244 is interpreted as

module 65	--	medium resolution
66	--	medium resolution
67	--	fine resolution
68	--	fine resolution .

From Figs. 15, 16 and 17 the following specification list for the Greater Mediterranean Region may be constructed:

SD Fields	SL Fields	SV Fields
37: 1111	5: 0011	5: 0044
41: 1111	9: 0002	13: 4400
45: 0001	17: 1221	
61: 1221	21: 4114	
65: 2244	29: 0100	
69: 2002	33: 1000	
85: 1210		
89: 4442		
93: 4002		
113: 1200		
117: 1000		

Rearrangement produces the following groups of words:

For an SD Field	For an SL Field	For an SV Field
8 coarse	4 coarse	1 coarse
4 medium	2 medium	1 medium
3 fine	1 fine	2 fine

Thus, for the Greater Mediterranean region, an SD field requires 15 words, an SL field requires 7 words, and an SV field 4 words--a total of 78 words for all nine component fields. To produce the data subset these 78 words are extracted and formed from the full set of 588 words for each date-time group.

In general, the production of a regional-focus data subset is accomplished in a single computer production run using the full data set of 8 tapes as input. The number of output tapes generated for any subset depends, of course, on the size of the region being considered but, typically, this would be a single tape.

7. THE ANALOGUE SEARCH AND SELECTION PROCESS

7.1 Introduction

Section 7 presents and discusses the MII methodology for providing the third basic component of any analogue selection system laid down in Section 3.2.1.

7.2 Preparing the Baseday

As defined in Section 3.1, the baseday may be specified as either the current synoptic situation or the synoptic situation corresponding to any date-time group in the history. Clearly, if the current situation is chosen, then analogue selection must begin with the bit-coding of its component fields and extraction of the regional-focus elements. For scenario matching using the current situation, the appropriate bit-strings must be formed incorporating the time element.

7.3 The Scoring Matrix

Each regional-focus subset representing a single synoptic situation, consists of 27 subgroups of words, thus:

3 ranges-of-scale (SV, SL, SD)
x 3 contour values (1000-mb, 500-mb, 500-1000-mb thickness)
x 3 resolutions (coarse, medium, fine).

Each analogue candidate from the history is scored by comparing its subset to that of the baseday, the count of the number of matching bits being a measure of the similarity between the patterns corresponding to the two situations. The counting of matching bits proceeds in stages,

commencing with coarse resolution words, then medium resolution words, and ending with fine resolution words. At each stage there is a "gate"--if the number of matching bits does not reach an assigned minimum level, then the analogue candidate is rejected at that stage. This procedure speeds up the selection process considerably.

The counting of matching bits and gate checks for minimum counts proceeds as follows:

Count	Coarse	SV500	
"	"	SV1000	
"	"	SV5-10	
"	"	SL500	
"	"	SL1000	
"	"	SL5-10	
"	"	SD500	
"	"	SD1000	
"	"	SD5-10	
			Total the Coarse counts
Count	Medium	SV500	
"	"	SV1000	
"	"	SV5-10	
"	"	SL500	
"	"	SL1000	
"	"	SL5-10	
"	"	SD500	
"	"	SD1000	
"	"	SD5-10	
			Total the Medium counts

Count Fine SV500

Total the SV500 counts

" " SV1000

Total the SV1000 counts

" " SV5-10

Total the SV5-10 counts

" " SL500

Total the SL500 counts

" " SL1000

Total the SL1000 counts

" " SL5-10

Total the SL5-10 counts

" " SD500

Total the SD500 counts

" " SD1000

Total the SD1000 counts

" " SD5-10

Total the SD5-10 counts

Total the Fine counts

In the above procedure for counting matching bits there are 39 gates, each of which must be passed by an analogue candidate before being considered for the next stage in the selection process. In addition to a listing of gate values to be exceeded, the system contains a listing of weight factors to be applied to the actual scores achieved at each stage. These weights can be adjusted (tuned) to emphasize any desired feature or combination of features (i.e., range-of-scale, level, thickness, resolution). A final count is then made which is the weighted total of the 39 contributing counts--this final count is the "analogue score" and is used to rank the selected analogues. If the number of analogues selected does not reach a specified minimum, e.g., 100, then the selection process is repeated after lowering all gates by 10%. For uncommon basedays this process may have to be repeated more than once.

7.4 Comparison with Monthly-Mean Fields

From the historical data, monthly-mean hemispheric climatologies have been compiled for all nine component fields in bit-coded format. A climatological regional focus subset may be extracted for any region; one such subset has been extracted for the Greater Mediterranean. The climatic group for the month of the baseday is forced past all gates, thus enabling its (weighted) final score to be used for reference purposes.

7.5 Probability Considerations

In any study and design of an analogue system it is of interest to consider the effects of chance in determining the degree of similarity obtained between a baseday and an analogue candidate. For RASS, a very simple model will be presented, based on modularization and bit-coding concepts.

Consider a parameterization scheme which enables the pattern over a module to be represented by a string of n bits. Each bit, of course, can have only one value--either 0 or 1. Assume that there exists a very large data base, containing a wide range of variabilities, in this bit-coded format. Then under these conditions, selecting any two situations at random and counting the matching bits should give a result in agreement with the laws of probability regarding random events.

From Bernoulli's formula:

$$P_n(B) = \frac{n!}{B!(n-B)!} p^B q^{n-B}$$

where $P_n(B)$ is the probability that an event will occur exactly B times out of n trials; p is the probability of the event occurring, common to each trial; and q is the probability of the event not occurring, i.e., $q = 1-p$.

Matching 2 n-bit words is equivalent to n trials where $p = q = 0.5$. Substituting for p and q we obtain

$$P_n(B) = \frac{n!(0.5)^n}{B!(n-B)!}$$

where $P_n(B)$ may be regarded as the probability that B bits will match out of a bit-string of n bits. Figure 18 shows curves of $P_n(B)$ against B for various values of n .

The main feature of note is that as n increases, the probability of obtaining a chance match of other than about 50% of the bits becomes very small--or, to put it the other way, it is very likely that about 50% of the bits will match by chance.

In an analogue system such as RASS which utilizes bit-matching (60 bits per module) the arrangement of bits within the bit-string is not completely random for several reasons. For example, the range levels for the specifying parameters are based on a distribution obtained by sampling, and there is a methodology for bit-coding the range intervals. Also, for an area such as the Mediterranean, pressure is generally higher in the south than in the north and this will, on average, be reflected in the number of bits matching by chance.

Thus on average it would be expected that, when matching two 60-bit RASS modules, rather more than 30 bits would match by chance. It is not possible to calculate the actual average because of the complex interactions involved--inherent in the RASS system itself, and in the meteorological situations and patterns. However such an average for a specified module or complete regional focus can be determined by experiments. Knowledge of

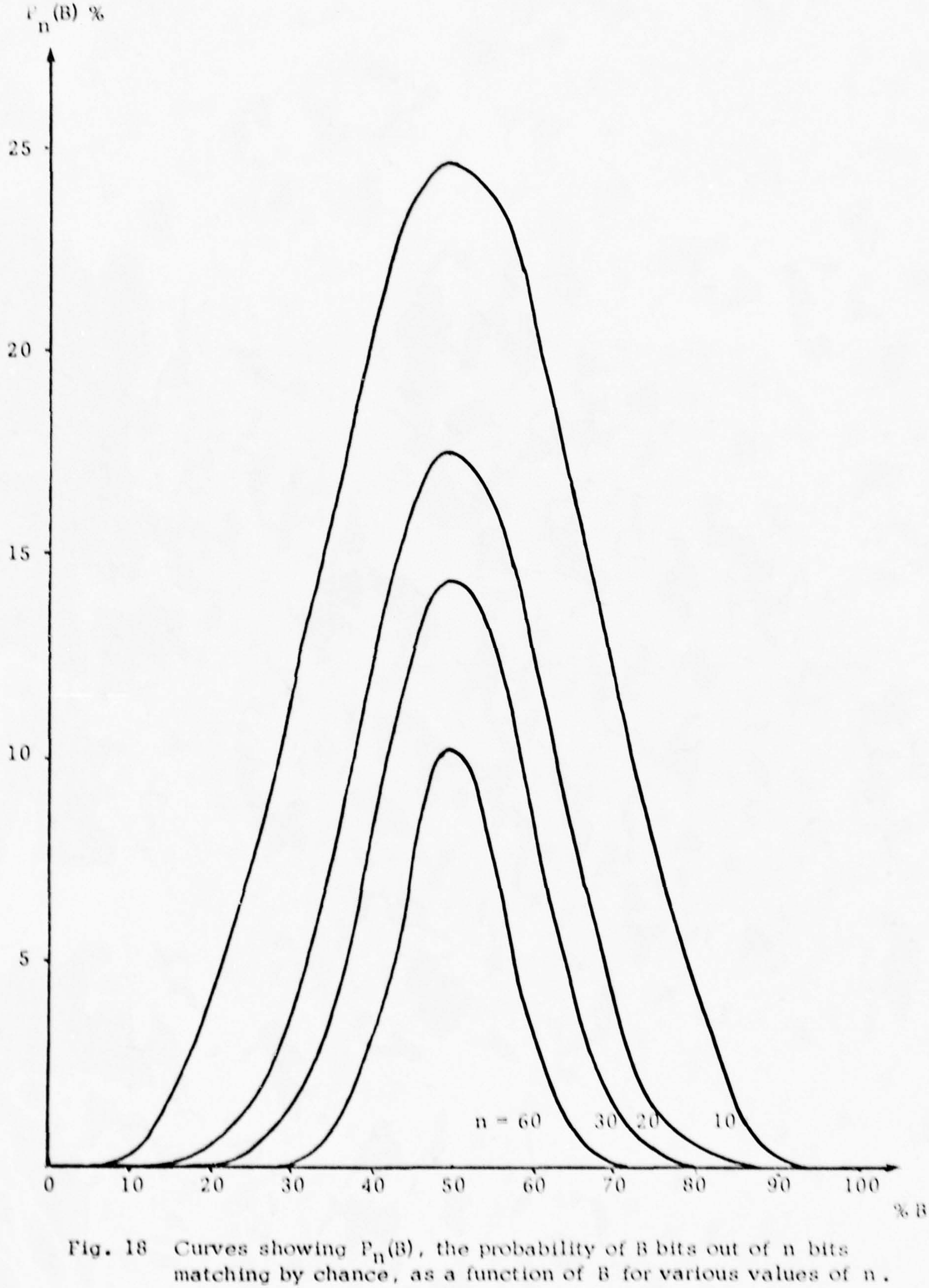


Fig. 18 Curves showing $P_n(B)$, the probability of B bits out of n bits matching by chance, as a function of B for various values of n.

this average determines the "zero skill" level of RASS matching[1] and is required for the setting of the selection gates (see Sections 7.3 and 8.1).

7.6 A Scheme for Scenario-Matching

7.6.1 The Time Tunnel

Section 6.1 described in simple terms how a bit-string representing a scenario is compiled in RASS. The equation given in that section can be generalized to cover a scenario of any length in time:

$$SC_{(\tau-n)\rightarrow\tau} = \sum_{x=0}^{x=n} S_{\tau-x}$$

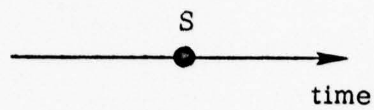
where x and n are measured in units of the time increment of the data base.

It is edifying to compare analogue and scenario matching by a simple pictorial technique. A meteorological situation S can be imagined as a point in N-space where N is the number of specifying parameters. The evolution of S with time may be illustrated thus:

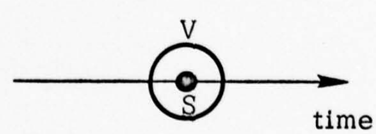
where S has been shown at a particular point in time. If S at this point in time is used as a basis for analogue selection then, of course, the time is that of the baseday.

[1]It is interesting to note that because of the bias toward matching, it is more difficult to find very bad analogues than very good analogues.

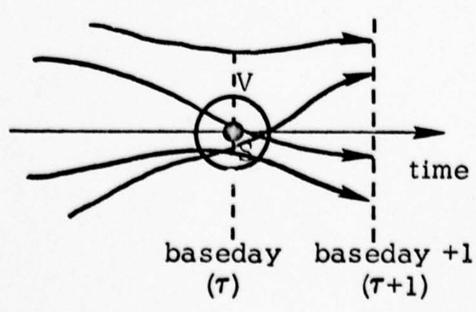
S would only be a point in N-space if the precise value of the specifying parameters were both known and used. However the technique of using range levels for coding the specifying parameters introduces uncertainty and S should be represented by a blob rather than a point, thus:



Even allowing for the uncertainty in S, a precise match is most unlikely to be found. In general, analogue candidates are scored and ranked, and the top-scoring analogues are selected. The maximum number of mismatching bits allowed before an analogue candidate is rejected describes a "volume" V in N-space about S, thus:



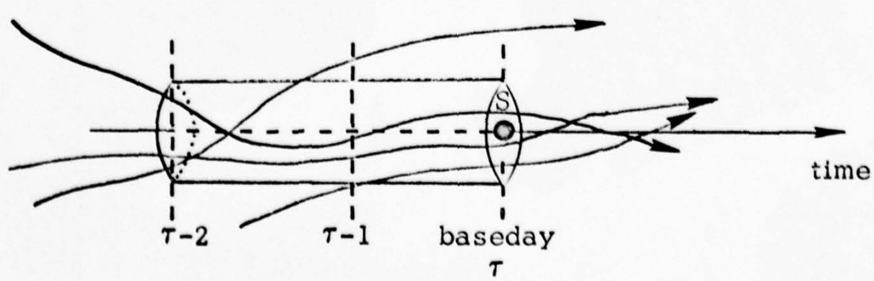
In analogue selection, a baseday is chosen and then the history is searched for meteorological situations whose evolution in time with respect to S passes through V; candidates not passing through V (the vast majority) are rejected:



An analogue forecast at time $(\tau+1)$ for meteorological situation S occurring at time τ is a compilation of all analogues passing through V, the compilation being performed on the analogue situations one time period later than when they passed through V.

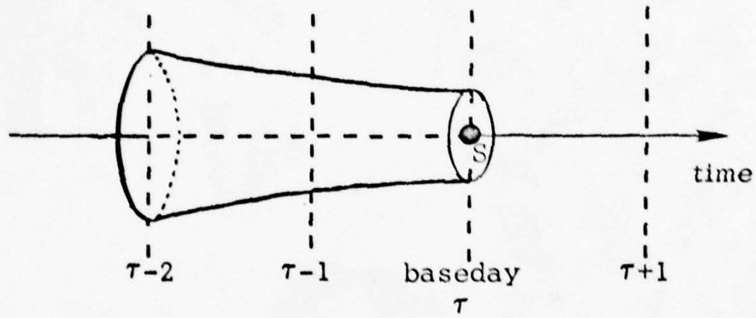
One point is immediately apparent from the above diagrams--the best analogue at time τ is not necessarily the analogue situation which will be closest to the evolution of S at time $\tau+1$. Thus an analogue forecasting system based on the single best analogue at time τ (the deterministic approach) is not likely to be consistently successful; a compilation of a "reasonable" number of analogues is required (the probabilistic approach). It may also be noted that the closest match(es) at time $\tau+1$ <u>may</u> lie outside V at time τ, and will therefore not be included in the compilation. However it is not possible to recognize these cases in advance and an analogue forecast system assumes that the evolution of analogues passing through V will more closely resemble the evolution of S than analogues not passing through V.

The diagrams shown above may be extended to illustrate scenario matching where, instead of an acceptable match at τ only, an acceptable match over a <u>period</u> of time is required. The following diagram is self-evident--to be successful, analogue candidates must enter and pass through a "time-tunnel":



The above diagram requires that the match be maintained over two time intervals, from τ-2 to τ. This is a two-period scenario match. Matches over longer periods may be obtained.

Note that a cylindrical tunnel requires that the number of matching bits remains within V for the whole time period. It is more realistic to accept a greater number of analogues at the start of the scenario matching process, the selection criteria becoming relatively more stringent as baseday is approached. The diagram now becomes:



Only those analogue candidates entering the time "funnel" at τ-2 and remaining within to emerge at time τ are used to compile the forecast for time τ+1.

The effect of a funnel may be achieved in a variety of ways, an obvious method being to set

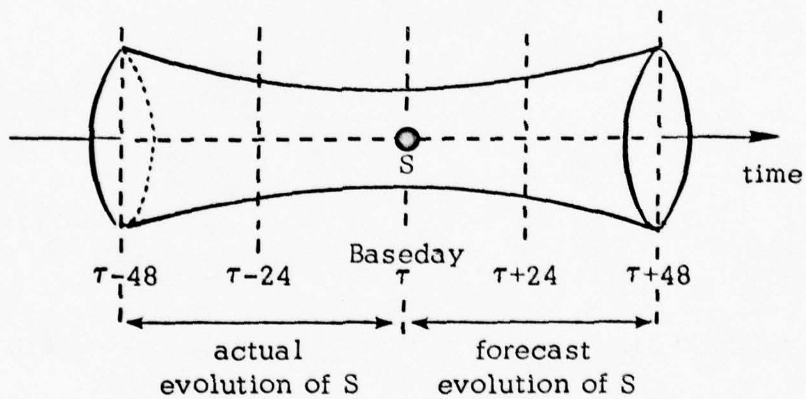
$$V_{\tau-2} > V_{\tau-1} > V_{\tau} \quad .$$

An alternative approach is to base the funnel on range-of-scale and pattern resolution considerations, using large-scale features and coarse reolution at first, then emphasizing smaller-scale features and finer resolution as baseday is approached. A method for doing this is described in the following Section.

7.6.2 Coupling RASS Forecasts to Numerical Forecast Models

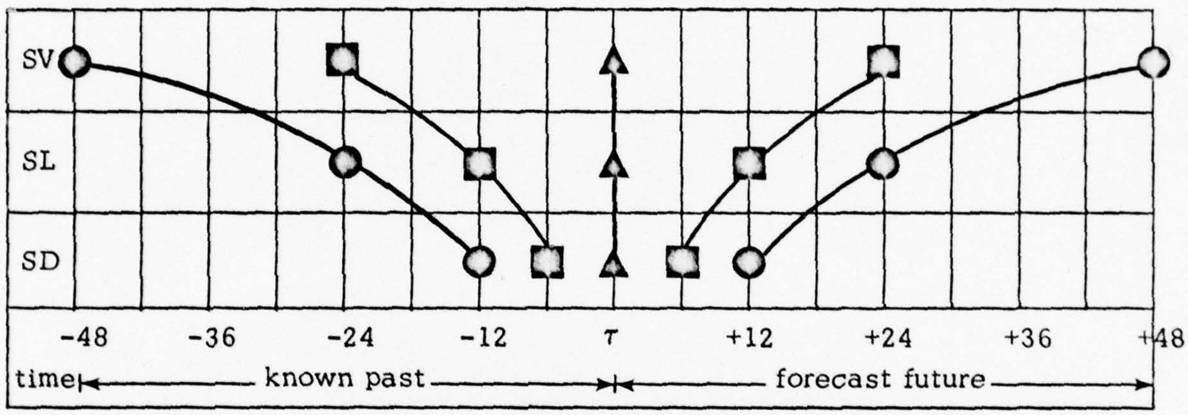
The pictorial technique developed above may be used to illustrate a technique for making fuller use of the skill inherent in a numerical forecast model, both by improving RASS forecasts and by extending the usefulness of the numerical model.

Considering the meteorological situation S at time τ as being the current situation, scenario matching from say τ-48 hours to τ can be carried out as previously described. Now assume that a PE (or other) model is available which demonstrates useful skill out to τ+48 hours. The forecast situations from this model can be used to extend the "time funnel" into the future, thus making use of the skill in the PE model to select analogues for times greater than τ+48 hours. Thus:



Only analogue candidates which remain within V for the whole range of τ ($\pm$ 48 hours) are used to compile analogue forecasts for forecast times greater than 48 hours. Note that the above diagram need not be symmetrical. For example, $V_{\tau+24}$ and $V_{\tau+48}$ need not be equal to $V_{\tau-24}$ and $V_{\tau-48}$ respectively, and neither do equal periods about the baseday have to be used. In fact, the more confidence that can be placed in the PE model, the less $V_{\tau+24}$ and $V_{\tau+48}$ should be.

A method for producing a bit-string to select analogue scenarios based on the known past evolution of S and its forecast future evolution is shown below. (This method is part of the overall design of RASS and its use is demonstrated in the two examples discussed in Section 8.)



Key: Coarse resolution only

Coarse resolution plus medium resolution supplement

Full resolution (coarse plus medium and fine resolution supplements)

Note that the ranges-of-scale (3) utilized in the bit string depend on time, as do the degrees of resolution (3) employed.

It is considered that the ability to couple analogue scenarios to a numerical forecast model such as the FNWC PE model is a unique and particularly significant development. Not only does the technique promise to allow the information provided by the PE model to be usefully extended by several days, but it should also allow the deterministic nature of the

PE forecast to be converted into probabilistic terms. In other words, if the deterministic result of the PE model is regarded as the most likely evolution from the current situation, then a selection of appropriate analogues will allow other but less likely evolution possibilities to be determined. Such a capability is of considerable operational significance and of direct relevance to the use of operational analysis techniques for planning purposes. However at this stage of RASS development the many potential uses of scenario matching have yet to be explored and exploited.

8. TUNING AND VERIFICATION PROCEDURES

8.1 Tuning

There are basically two sets of tuning controls--the selection gates and the weight factors assigned to the number of matching bits achieved by an analogue candidate at each phase of the selection process. As discussed in Section 7.3 and as presently used in RASS, essentially the selection gate levels control the number of analogues selected while the weights decide the final ranking by adjusting the relative significance of any chosen pattern characteristics.

8.1.1 The Selection Gates

In carrying out the selection process it is important to select a "reasonable" number of analogues. If too many are scored, selected and ranked, computer resources are being expended unnecessarily, and if too few are selected the process has to be repeated after lowering the gate levels--which again wastes computer time. (It is not possible to know how many analogues will be selected for an arbitrary baseday. The selection process could be stopped once a chosen number is reached but this is not a realistic approach as the best analogues may not have been reached in the search.)

Selection of this "reasonable" number has to be based on knowing, on average, how many analogues will be selected from the appropriate season for a randomly-chosen baseday. Selection gates are set so that this average number is "reasonable". Of course, if any particular baseday is a commonly-occurring situation then a larger number will be selected, and vice versa[1]. Determining this average number of selections involves those considerations discussed in Section 7.5.

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[1]The fact that a very low number of analogues is selected for a given baseday is information of value in that it informs that an unusual event is occurring.

8.1.1.1 Persistence

A method for arriving at an approximation to this average number of analogues to an arbitrary baseday is to select a small number of basedays and match them (by counting matching bits) against their own evolution. Thus if S_τ is the baseday and n is an integer number of days the procedure may be expressed by

$$S_\tau : S_{\tau+n} \quad , \quad n = 0 \rightarrow 15$$

where " : " indicates the process of counting matching bits. In effect this procedure detects the persistence of S_τ out to 15 days.

Figures 19, 20 and 21 show the persistence out to 15 days of the nine component fields using all 31 days of January 1967 as basedays. Similar curves are discussed in greater detail in Section 8.2. However with regard to selection gates, if it is assumed that there is zero persistence after 15 days (i.e., that $S_{\tau+15}$ is independent of S_τ) and that January 1967 was a "typical" January, then the match coefficient at $S_{\tau+15}$ gives a measure of the number of bits likely to match by chance in all Januaries.

To obtain this measure correctly for, say, January, requires matching two randomly selected situations from all Januaries in the data base, repeating this process a large number of times, then taking a mean of the count of matching bits. However, for the purposes of setting selection gate levels the approximate process has been found satisfactory with regard to selection of a reasonable number of analogues (see also Section 8.2).

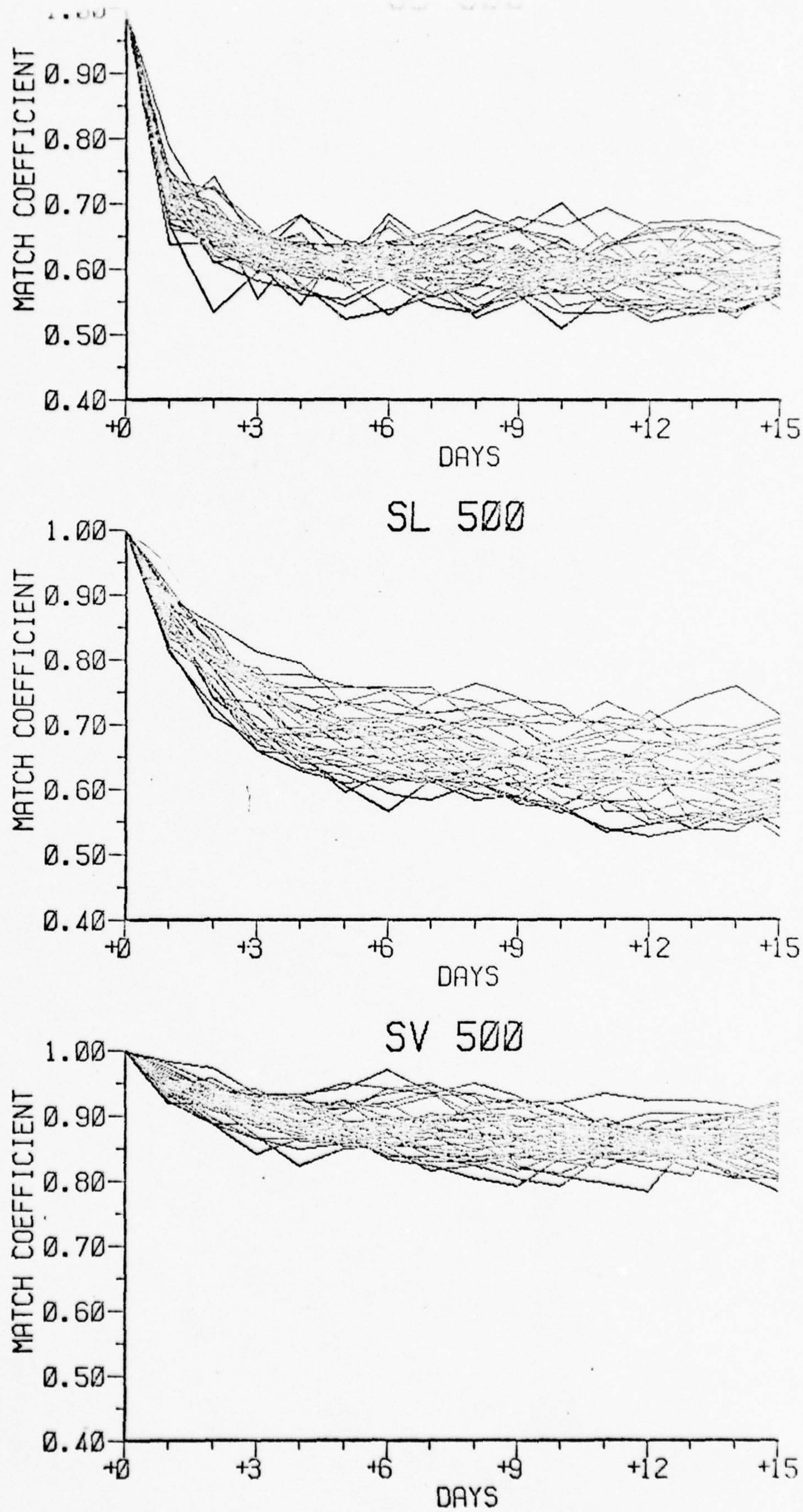


Figure 19 January 1967 500-mb Persistence

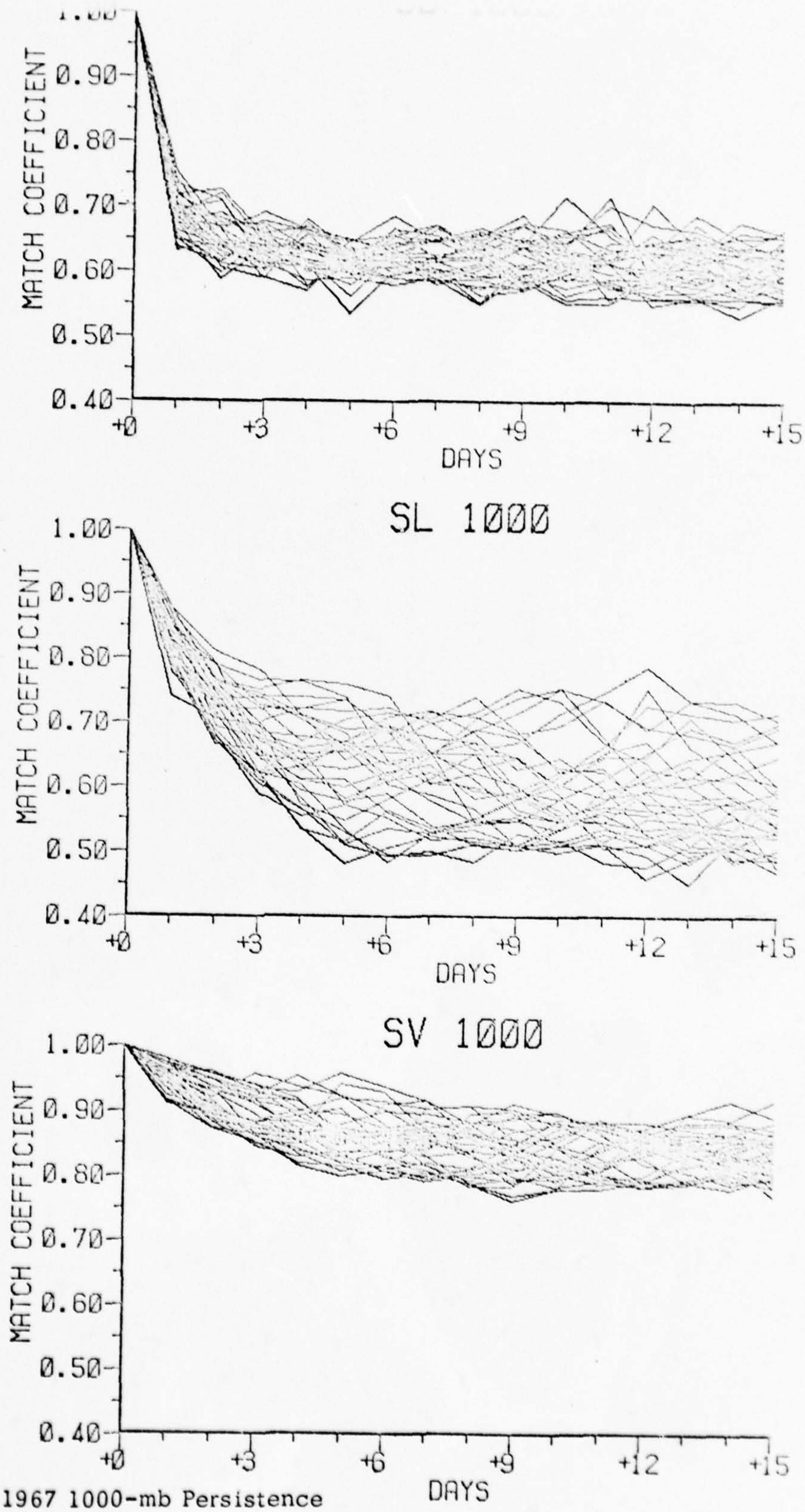


Figure 20 January 1967 1000-mb Persistence

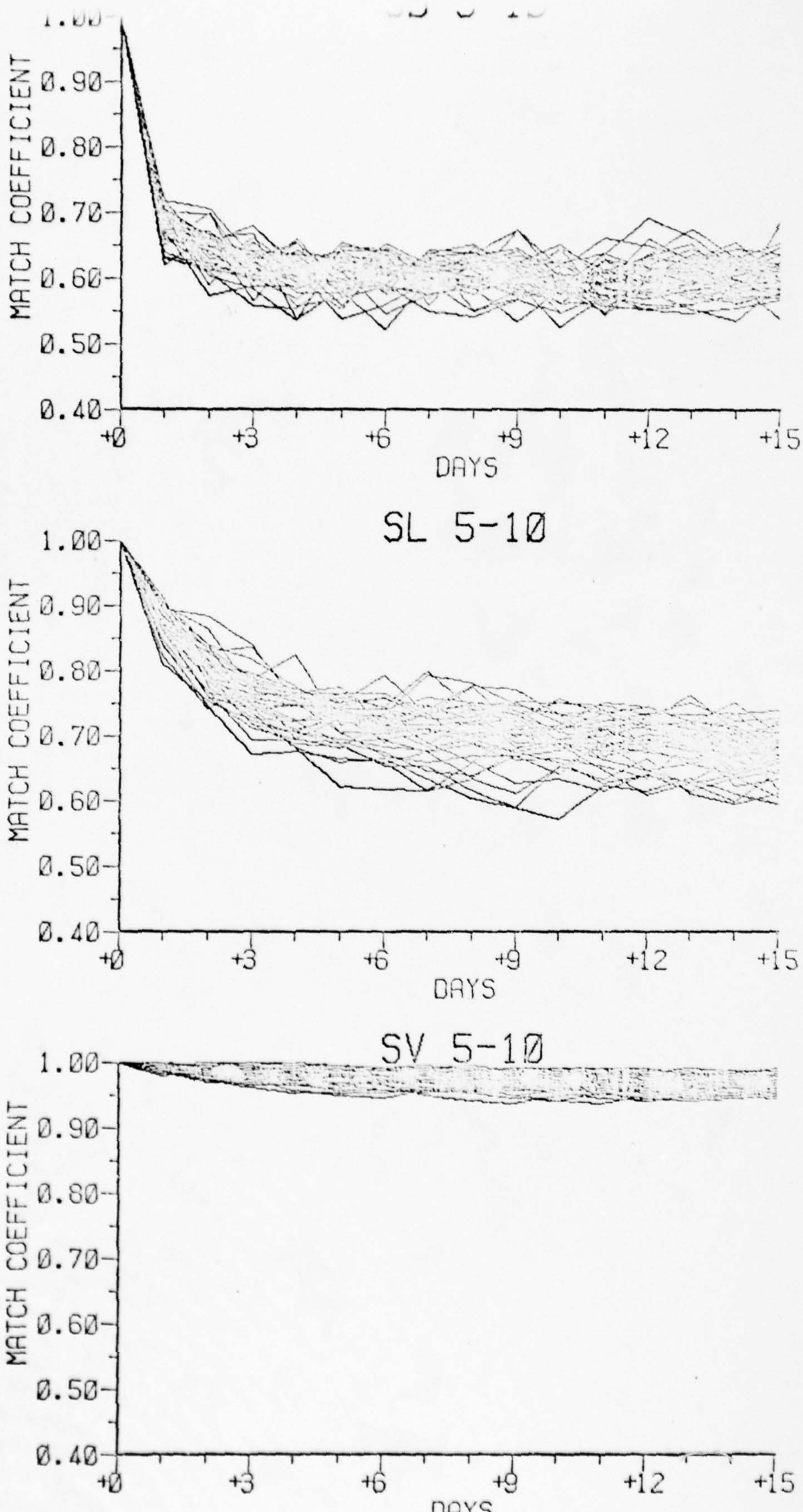


Figure 21 January 1967 500-1000-mb Persistence

8.1.2 Weight Factors

Suitable choice of the weighting factors applied to the number of matching bits at each stage of the selection process allows the relative significance of any input component to the final score to be controlled. There are 9 of these components--3 ranges-of-scale x 3 degrees of resolution. Basically (and obviously) the smaller the range-of-scale and the finer the degree of resolution, the more difficult it is to obtain good analogues.

The three ranges-of-scale are adequate to represent disturbances of the atmosphere in space. However, associated with each range-of-scale there is a range-in-time; SV disturbance components vary slowly, SL components more quickly, and SD components vary rapidly. To capture time-variabilities on the SV scale, SV analyses in the data base should be at intervals of 1 or 2 days; the available data base contains SV analyses with this frequency (see Section 3.2.2.2). For SL analyses, the analysis frequency should be every 12 hours; the available data base is adequate for some periods of the history but not for all the history. However, to capture time-variabilities on the SD scale, SD analyses are required every 6 hours with an interpolation capability down to 1 hour; in this respect the data base is completely inadequate.

To illustrate the effect of this lack of resolution-in-time on the SD range-of-scale, imagine that good analogues for a particular baseday have been found in the SV and SL ranges-of-scale. Because SD analyses are only available at 12-hour or 24-hour intervals, they will appear to be scattered almost randomly through these analogues and their subsequent evolution. In fact, based on 24-hour analyses, the SD range-of-scale (in time) appears as "noise". A forecaster requires synoptic analyses every 6 hours for a large area and every 3 hours for local-area forecasting; this requirement is no less critical for RASS which matches synoptic situations and their evolutions in space and time.

The need to interpolate SD features to a time-resolution of 1 hour is to provide a "phase-matching" capability. For example, an analogue may match the baseday situation very well with regard to the SV and SL features, but the evolution of analogue SD features may lead or lag those of the baseday by a small number of hours. The analogue should therefore be adjusted to correspond to the "phase" of the baseday--a feasible process given sufficient time-resolution in the data base.

SD features are largely responsible for operationally significant weather factors and therefore their importance should be reflected in analogue selection and ranking. However at this time, due to the lack of resolution in the data base along the time axis, very little weight can be given to the SD range-of-scale. Given the currently available data base, the SL range-of-scale is the smallest that can be matched with any degree of success. Therefore the weight factors assigned to SL fields are accentuated accordingly.

8.2 Persistence Climatologies

Section 8.1.1.1 discussed the relevance of persistence in establishing selection gate levels to ensure that an adequate but reasonable number of analogues are chosen in, ideally, one pass through the available history. However the main use of persistence scores is to establish a "zero skill" level against which to compare the effectiveness of RASS; a variety of climatologies has been derived for this purpose.

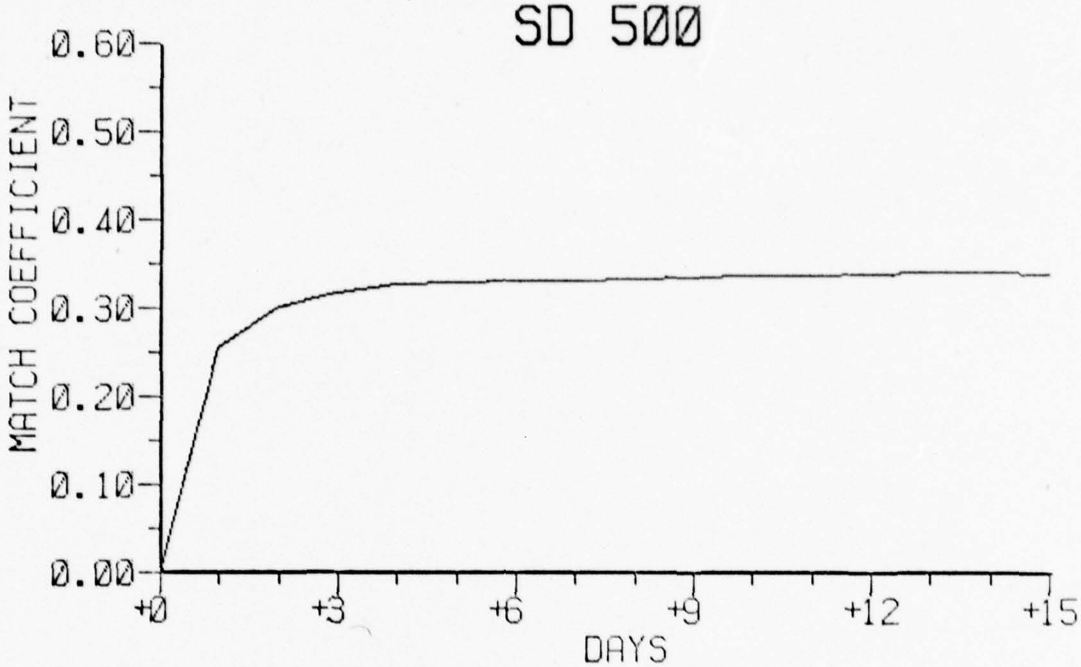
In all climatologies the formulation given previously has been used out to 15 days; i.e.,

$$S_{\tau} : S_{\tau+n} \quad , \quad n = 0 \rightarrow 15 \quad ,$$

where τ assumes a range of values depending on the climatology required. For example to derive an all-Januaries climatology, τ covers the range $1 \rightarrow 31$ for all Januaries in the data base. Note that a January climatology is based on a 15-day period starting in January but including contributions from situations up to mid-February. From the results for each January a mean curve is calculated for the all-Januaries persistence climatology.

The climatology to be used for verification of RASS is the monthly climatology appropriate to the baseday. This monthly climatology has been derived for each month (12), by each component field (9), and by each degree of resolution plus one all-resolution category (4). In all cases the modules incorporated in the climatology are those appropriate to the range-of-scale and resolution considered; these modules are shown in Figs. 15, 16 and 17.

In addition to monthly values, seasonal and annual persistence climatologies have also been derived. Figure 22 shows an example of an all-years persistence climatology using equal weight factors (=1) at each selection gate; it thus falls in the all-resolution category. (Note that in this figure the match coefficient is the fraction of mis-matching bits--compare with Figs. 19-21 which use the fraction of matching bits.)



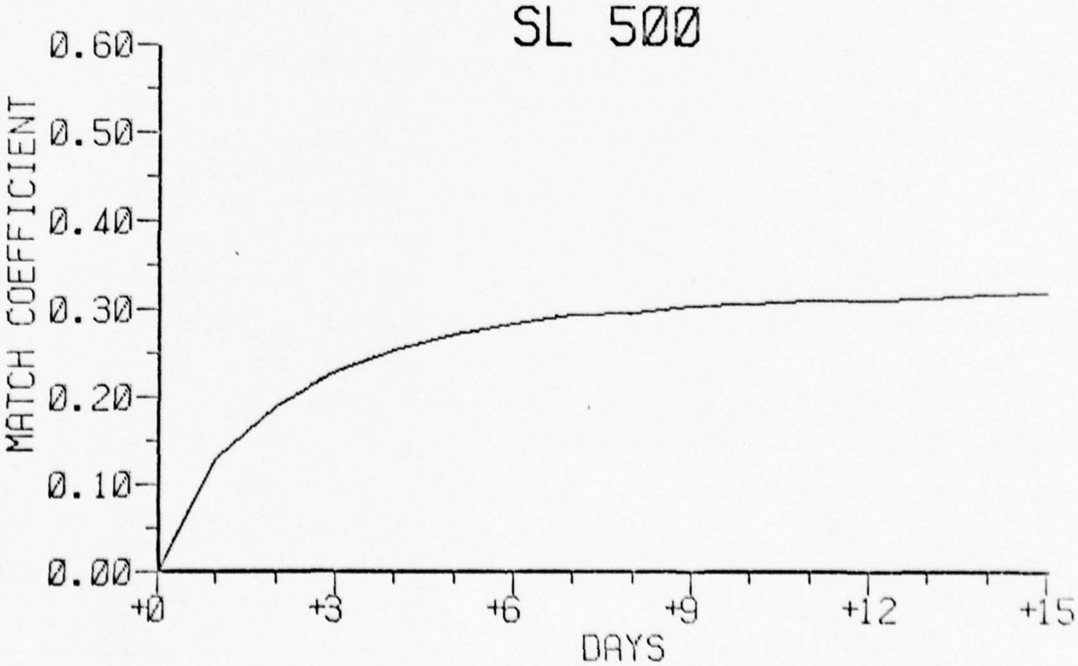


Fig. 22 Mean annual persistence climatologies for the three ranges-of-scale, 500-mb level.

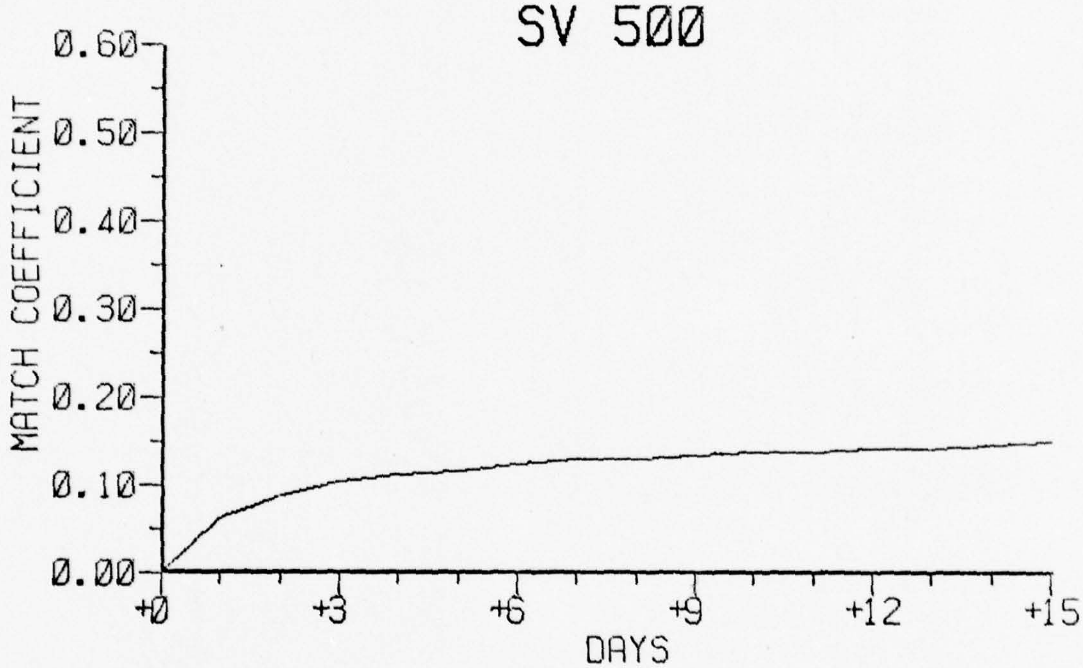


Fig. 22 continued

8.3 The RASS Verification Scheme

The RASS methodology for selecting, scoring and ranking analogues is described in Section 7. As explained, the selection process includes considerations of 3 ranges-of-scale and 3 degrees of resolution. For a regional focus, the actual terrestrial area involved in analogue selection is a function of both resolution and range-of-scale. Thus, for example, Figs. 15-17 show the modules and associated ranges-of-scale and degrees of resolution for the Greater Mediterranean regional focus. It will be noted that the area involved in analogue selection is much greater than the Mediterranean Sea itself.

The analogue verification scheme is designed to operate on a smaller area than that involved in analogue selection. This area (in terms of modules) is called the OBJECT REGION, and is presently defined as those modules, appropriate to each range-of-scale, for which full resolution is used in analogue selection. Thus, for the Greater Mediterranean regional focus, the object region modules are as follows:

SD range-of-scale. Modules no. 67, 68, 89, 90, 91, 93. (See Fig. 15.)

SL range-of-scale. Modules no. 21, 24. (See Fig. 16.)

SV range-of-scale. Modules no. 7, 8, 13, 14. (See Fig. 17.)

Only these modules are used in the RASS verification scheme.

The verification process currently is performed out to eight days from the time of the selected baseday; this verification period can be varied. There are basically three stages involved in the verification procedure:

a. Persistence Verification. For a selected baseday of time τ (BD_τ) the ensuring events are matched against BD_τ. Thus, using the nomenclature previously explained:

$$BD_{\tau+x} : BD_\tau \quad , \quad x = 0 \rightarrow 8 \quad .$$

This score shows the effectiveness of persistence forecasting, i.e., the effect of assuming that the baseday situation remains unchanged for 8 days.

b. Climatology Verification.[2] The baseday, BD_τ, and its ensuing scenario, is matched against the climatology appropriate to the calendar month (C_{BD}) of the baseday. Thus:

$$BD_{\tau+x} : C_{BD} \quad , \quad x = 0 \rightarrow 8 \quad .$$

This score shows the effect of assuming that climatologically normal conditions will prevail for the next 8 days.

c. Analogue Verification. The day-by-day evolution of each of the top N analogues (where N can be specified) is matched against the evolution of the baseday situation. Thus:

$$S_{n,\tau'+x} : BD_{\tau+x} \quad , \quad n = 1 \rightarrow N \quad , \quad x = 0 \rightarrow 8$$

where τ' is the date-time of the selected analogue S_n.

Examples of verification records are given in Sections 8.4.1 and 8.4.2.

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[2] As used in this sense, climatology refers to the mean (in time) of the component fields.

Verification of course, can only be carried out using historical information. Thus in an operational mode the verification scores of analogues selected for a particular baseday will not be available until 8 days later.

In the RASS verification scheme, records are stacked as they are produced and, once an adequate sample has accumulated, various statistical measures can be produced to show the performance of analogue selections over, for example, the previous month.

8.4 Demonstration of Current RASS Capabilities

The current capabilities of RASS are demonstrated by application to two scenarios[3] for the Greater Mediterranean region of focus chosen from historical records. The first demonstration is based on the scenario ensuing from 12Z 22 AUG 69 and is presented in Section 8.4.1; the second demonstration, presented in Section 8.4.2, is based on the scenario ensuing from 12Z 18 OCT 75.

While studying the tables and charts presented for each demonstration, the following points should be kept in mind:

a. As discussed in Section 8.1.2, because of the inadequacy of the data base with regard to SD features, little weight can be given to this range-of-scale. In general, therefore, a good match for SD features is less likely than for the more-strongly accentuated SL features.

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[3] Dates specified by NEPRF.

b. Analogue selection is based on <u>scenario-matching</u>, discussed in Section 7.6, using a "double-ended time tunnel" of the type shown in Section 7.6.2. In using this time funnel however, the "forecast future" shown on the diagram was available from historical records. A suitable input to such a time funnel is shown on page 58, but the current data base does not contain all the required analyses. The procedure adopted to circumvent data base deficiencies was to assume that any missing field was identical to the last available analysis of that field. The effect of this assumption of persistence is, of course, particularly severe when matching the SD range-of-scale.

c. The analogue scenarios presented in chart form (two scenarios for each baseday scenario) must not be regarded as deterministic. The scenarios given should be regarded as being only two examples of a set of possible scenarios evolving from initial conditions similar to those of the baseday scenario. (The other possible scenarios have not been included in this Report due to space limitations.) The <u>set</u> of possible scenarios would be used, for example, to compile a forecast of surface winds in probabilistic terms--there are many other potential uses.

d. The term "climatology" used in each of the two verification summaries refers to the monthly <u>mean</u> field for each of the nine component-fields. This mean field, of course, is relatively flat and featureless and has no utility in generating weather information--no more than weather information for the Mediterranean can be produced from, say, a monthly-mean chart of sea-level pressure. Comparison of the fields representing an actual meteorological situation with the mean fields merely yields a measure of the degree of pattern

similarity between these two sets of fields; this measure has little significance.

The two demonstrations are presented without discussion of the tables or charts as significant similarities and differences are readily apparent by visual inspection.

The first table in each Section shows the top 25 analogues. For each selection, two rows of figures are given; the upper row shows scores based on the baseday situation, while the lower row shows scores based on the baseday scenario. (The ordering of the selections was based on final scenario scores.) All scores are given in parts per 1000 (i.e., % x 10). The first 9 columns show the scores of unweighted matching bits for each of the nine component fields. The sum of the unweighted bits, normalized to 1000, is shown in column 10. The final column shows the final score based on the weighted sum of matching bits, again normalized to 1000.

As will be noted the top eight analogues for the summer case and the top nine analogues for the winter case were part of the same sequence as the baseday and these cases, therefore, have been excluded from the verification summaries. These are given in the next four tables in each Section and show, for the baseday to baseday+8 days, the scores for each of the nine component fields. These scores are in terms of unweighted matching bits, apart from the final row which is the weighted sum of matching bits. For each verification summary the mean-field climatology is given first (see paragraph d above), followed by persistence. Then follow the scores for the ten scenarios selected as most closely resembling the baseday scenario.

Each demonstration presents charts for 3 scenarios showing the SL500, SL1000, SD500 and SD1000 component fields at day 0, day 2 and day 5. The first scenario in each case is for that of the baseday followed by two scenarios chosen from the list of analogue selections. These are as follows:

	1st Scenario	2nd Scenario	3rd Scenario
Section 8.4.1	12Z 22 AUG 69 (baseday)	12Z 04 SEP 52 (selection 10)	12Z 15 JUL 66 (selection 11)
Section 8.4.2	12Z 18 OCT 75 (baseday)	12Z 26 APR 72 (selection 11)	12Z 10 NOV 68 (selection 12)

8.4.1 RASS Demonstration 1: Baseday 12Z 22 AUG 69

List of contents:

(To facilitate study of the charts, each scenario has been separated from the next by an unnumbered yellow insert; within each scenario sets of component fields are separated by an unnumbered blue insert.)

ANALOGUE SELECTIONS FOR 12Z 22 AUG 69 MEDITERRANEAN REGION

	SV			SL			SD				
ANALOGUE DTG	500	1000	5-10	500	1000	5-10	500	1000	5-10	TOTAL	FINAL
1. 12Z 22 AUG 69	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000 1000	1000
2. 00Z 22 AUG 69	971 980	971 965	954 960	942 950	942 929	958 957	817 847	834 848	820 835	875 884	936
3. 00Z 23 AUG 69	983 985	979 975	958 963	964 953	924 925	958 961	833 836	834 840	845 842	885 882	935
4. 12Z 21 AUG 69	967 983	971 967	983 988	921 923	909 893	924 941	782 792	799 800	758 777	843 844	913
5. 12Z 23 AUG 69	975 980	971 968	988 990	915 919	845 882	945 940	799 794	756 772	826 809	849 844	903
6. 00Z 21 AUG 69	958 973	958 948	946 957	900 895	885 854	903 915	751 757	745 749	725 742	811 808	884
7. 00Z 24 AUG 69	971 967	946 940	958 967	870 883	818 828	897 920	733 750	720 731	723 742	795 800	865
8. 12Z 20 AUG 69	958 973	954 950	979 985	852 868	845 820	900 892	713 721	721 729	710 720	790 786	864
9. 12Z 20 AUG 52	954 962	892 885	954 957	858 882	833 833	830 856	755 747	685 703	721 726	783 783	852
10. 12Z 04 SEP 52	933 940	950 937	925 930	870 859	894 852	858 833	688 676	699 699	702 689	776 757	852
11. 12Z 15 JUL 65	954 973	908 903	954 960	870 841	812 824	858 842	750 745	730 739	708 710	791 783	851
12. 00Z 16 JUL 65	950 958	917 907	967 968	852 840	833 827	852 847	742 740	701 722	707 711	784 778	850
13. 12Z 16 JUL 66	958 968	908 905	967 960	845 840	824 821	855 844	760 757	727 731	730 722	795 786	849
14. 00Z 15 JUL 66	958 972	913 912	967 968	852 835	818 815	864 838	713 708	715 713	685 684	776 763	845
15. 12Z 05 SEP 52	908 932	913 917	946 947	858 854	821 838	845 840	701 695	697 717	707 701	770 766	844
16. 12Z 24 AUG 69	929 942	950 938	979 978	852 862	758 796	894 908	698 706	688 705	699 703	769 771	842
17. 12Z 15 AUG 61	929 945	875 898	942 942	852 843	812 798	855 857	732 732	697 736	732 736	780 782	841
18. 12Z 16 AUG 61	929 947	896 898	933 938	839 839	830 816	842 850	712 698	714 707	706 707	774 763	841
19. 00Z 15 JUL 70	925 938	888 887	937 947	864 855	845 815	827 829	711 705	729 721	669 672	770 759	841
20. 12Z 19 AUG 52	958 960	908 898	954 953	870 875	800 796	867 866	695 706	679 691	710 716	769 767	840
21. 12Z 21 AUG 52	942 960	900 892	942 948	858 866	788 806	858 851	687 708	685 684	686 708	759 762	838
22. 12Z 14 JUL 66	954 973	908 910	954 963	839 826	821 812	821 829	720 719	704 705	687 670	770 759	838
23. 00Z 25 AUG 69	942 952	908 917	958 967	848 849	776 787	882 891	671 685	684 685	688 682	758 754	836
24. 12Z 15 JUL 70	917 947	879 882	933 937	873 855	821 807	848 841	693 690	687 701	650 659	754 749	835
25. 12Z 04 SEP 60	908 935	937 932	925 943	842 826	827 791	839 859	701 710	749 751	680 692	774 770	835

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 22 AUG 69
ANALOGUE: CLIMATOLOGY
RANK : 0
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	937	946	942	933	967	975	971	942	929
	1000:	942	937	933	937	967	950	950	963	933
	5-10:	983	996	988	958	954	954	925	946	946
SL	500:	808	792	783	775	800	783	792	808	833
	1000:	742	783	758	775	750	775	758	800	792
	5-10:	842	850	850	850	817	817	850	858	875
SD	500:	653	697	683	628	608	639	631	661	650
	1000:	669	694	681	675	639	672	636	678	664
	5-10:	672	697	664	650	605	619	603	667	625
FINAL		845	870	835	852	842	855	850	856	842

BASEDAY : 12Z 22 AUG 69
ANALOGUE: PERSISTENCE
RANK : 0
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	1000	975	929	896	904	929	933	904	892
	1000:	1000	971	950	929	925	925	933	921	875
	5-10:	1000	988	979	950	937	937	925	937	937
SL	500:	1000	933	858	883	825	825	833	850	808
	1000:	1000	858	783	817	825	867	850	842	833
	5-10:	1000	958	892	875	825	842	842	833	800
SD	500:	1000	756	647	586	594	625	639	597	608
	1000:	1000	731	678	706	669	725	667	664	694
	5-10:	1000	808	681	639	603	653	664	656	658
FINAL		1000	897	844	842	831	862	858	831	832

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 20 AUG 52
RANK : 1
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	954	950	929	883	908	913	908	858	829
	1000:	892	904	858	925	875	892	888	846	779
	5-10:	954	954	933	937	937	950	913	954	950
SL	500:	867	875	842	817	800	800	767	783	758
	1000:	858	900	833	783	700	758	758	792	758
	5-10:	817	883	892	908	858	792	842	842	825
SD	500:	694	722	722	522	619	658	656	625	669
	1000:	633	706	697	628	617	647	631	639	717
	5-10:	681	697	733	578	633	639	703	650	625
FINAL		865	902	857	827	805	844	832	835	824

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 04 SEP 52
RANK : 2
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	933	925	921	917	904	929	929	858	904
	1000:	950	917	892	867	921	921	933	946	921
	5-10:	925	950	958	975	963	971	971	871	937
SL	500:	925	858	775	767	817	750	800	867	842
	1000:	917	867	733	742	692	667	717	753	758
	5-10:	917	892	792	833	850	825	850	850	883
SD	500:	678	772	742	672	658	697	608	647	725
	1000:	681	756	694	714	736	639	603	736	669
	5-10:	706	750	703	700	661	661	667	664	739
FINAL		901	872	805	804	830	816	821	830	821

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 15 JUL 66
RANK : 3
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	954	950	925	917	975	950	942	917	871
	1000:	908	904	875	883	921	900	875	858	812
	5-10:	954	971	933	946	946	954	917	937	933
SL	500:	908	917	933	817	775	725	775	858	825
	1000:	842	917	842	767	717	742	708	858	792
	5-10:	917	908	892	908	850	808	842	842	875
SD	500:	703	753	742	644	658	572	639	686	578
	1000:	703	750	694	658	697	619	681	697	592
	5-10:	678	678	689	683	619	553	592	633	633
FINAL		881	914	886	858	831	812	807	840	831

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 00Z 16 JUL 66
RANK : 4
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	950	904	896	925	950	925	925	879	829
	1000:	917	904	908	904	946	888	892	871	825
	5-10:	967	958	954	933	950	937	921	925	929
SL	500:	892	908	900	792	750	725	817	900	800
	1000:	883	908	842	758	708	725	775	800	767
	5-10:	917	917	917	867	825	792	858	883	875
SD	500:	700	739	764	611	600	603	611	603	572
	1000:	664	747	683	667	664	631	689	672	561
	5-10:	669	681	739	644	581	578	592	592	647
FINAL		883	908	900	844	822	812	840	821	820

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 16 JUL 66
RANK : 5
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	958	954	950	950	958	929	946	883	842
	1000:	908	913	921	900	933	875	879	842	808
	5-10:	967	942	950	950	963	946	917	933	925
SL	500:	883	892	842	783	725	750	842	883	808
	1000:	842	833	800	753	717	742	817	783	742
	5-10:	917	908	908	850	825	825	833	892	867
SD	500:	725	761	739	628	625	664	667	594	531
	1000:	686	714	681	672	681	667	700	650	603
	5-10:	697	694	714	650	647	631	619	608	583
FINAL		869	887	890	841	818	818	852	823	821

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 00Z 15 JUL 66
RANK : 6
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	958	942	875	871	958	958	937	904	867
	1000:	913	904	867	879	908	913	879	871	842
	5-10:	967	963	950	925	929	942	925	942	933
SL	500:	908	892	917	875	783	750	750	850	858
	1000:	842	925	883	775	717	733	708	850	808
	5-10:	917	908	867	917	867	808	808	867	900
SD	500:	672	744	725	686	614	564	589	725	603
	1000:	739	689	744	672	669	619	656	736	653
	5-10:	678	672	681	692	631	536	561	633	606
FINAL		875	903	873	864	833	823	810	863	835

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 05 SEP 52
RANK : 7
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	908	925	942	904	904	917	879	908	883
	1000:	913	921	913	892	904	925	958	933	937
	5-10:	946	958	946	975	963	958	883	929	925
SL	500:	875	850	742	808	767	758	833	817	742
	1000:	875	775	742	733	642	667	700	733	750
	5-10:	900	808	817	850	858	817	875	850	833
SD	500:	650	755	728	706	667	617	622	697	750
	1000:	647	708	703	717	678	628	617	706	683
	5-10:	675	703	747	725	672	678	622	692	711
FINAL		866	836	801	842	808	803	814	820	792

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 15 AUG 61
RANK : 8
REGION : MEDITERRANEAN

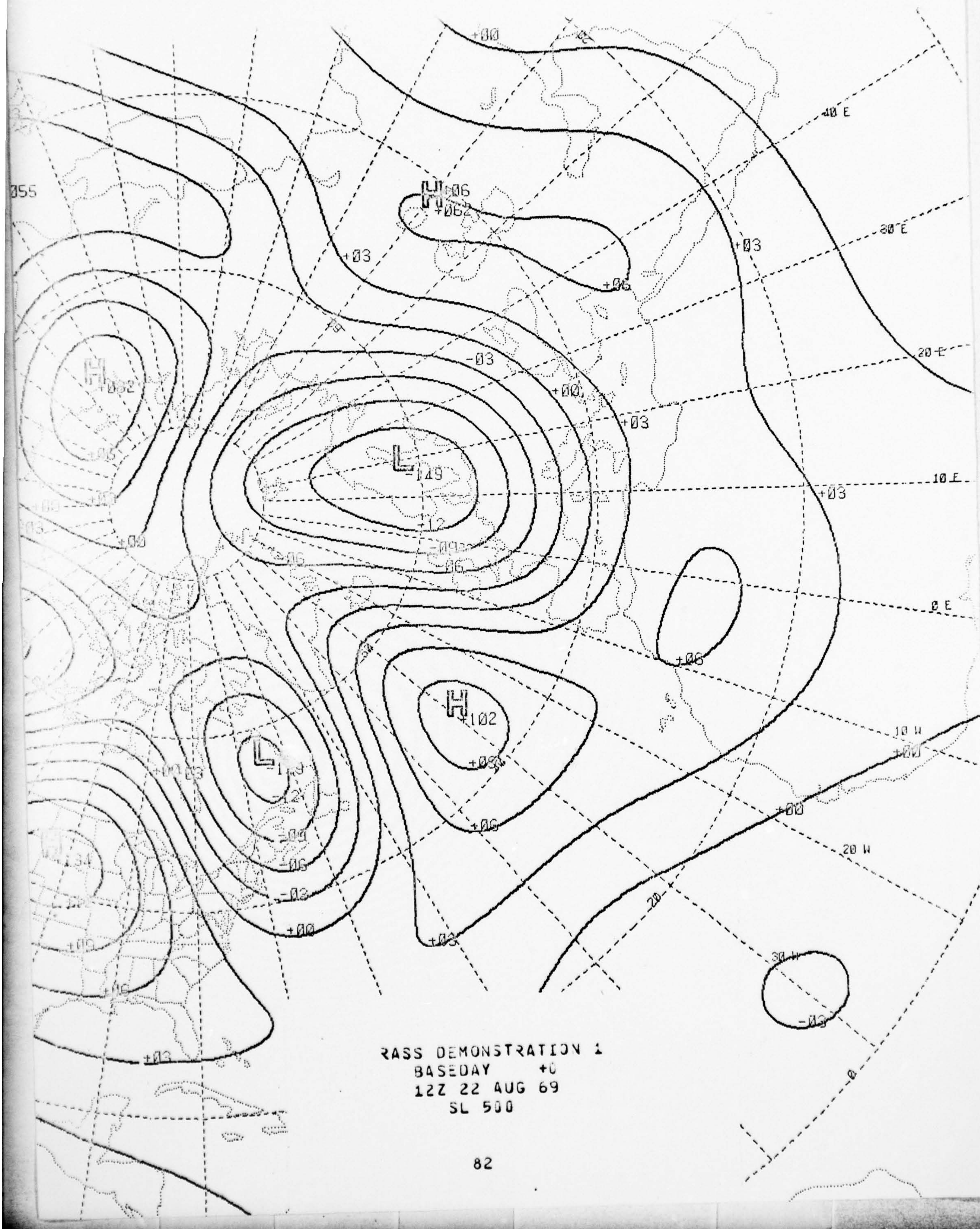
		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	929	921	892	779	867	863	863	838	846
	1000:	875	892	871	846	858	875	883	892	867
	5-10:	942	937	937	846	917	946	921	929	917
SL	500:	917	875	858	850	825	867	800	817	825
	1000:	850	875	775	800	792	792	783	783	817
	5-10:	917	908	875	808	833	875	883	850	817
SD	500:	725	742	661	603	564	639	608	697	658
	1000:	683	703	733	675	664	656	611	683	719
	5-10:	725	725	664	608	544	639	547	675	639
FINAL		878	874	837	805	820	851	844	827	834

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 12Z 16 AUG 61
RANK : 9
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	929	929	804	842	846	850	867	858	867
	1000:	896	908	875	821	850	875	904	913	863
	5-10:	933	946	850	929	929	925	933	908	929
SL	500:	875	833	825	867	867	792	817	850	758
	1000:	883	817	767	817	783	767	792	858	717
	5-10:	867	858	842	867	858	867	858	850	825
SD	500:	675	619	558	578	614	639	656	719	633
	1000:	689	658	619	606	661	619	697	706	686
	5-10:	667	681	583	569	628	669	572	747	625
FINAL		874	851	804	839	826	845	852	851	809

BASEDAY : 12Z 22 AUG 69
ANALOGUE: 00Z 15 JUL 70
RANK : 10
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	925	921	892	892	900	921	896	879	871
	1000:	888	913	883	875	879	913	913	900	892
	5-10:	937	917	921	904	913	904	917	892	904
SL	500:	908	858	850	892	850	808	717	725	700
	1000:	900	817	792	817	767	733	683	683	658
	5-10:	867	867	842	858	842	842	750	783	717
SD	500:	686	711	706	672	625	628	675	614	658
	1000:	722	731	669	628	617	692	683	656	667
	5-10:	639	656	639	664	636	619	667	611	600
FINAL		889	867	843	864	817	810	772	768	734



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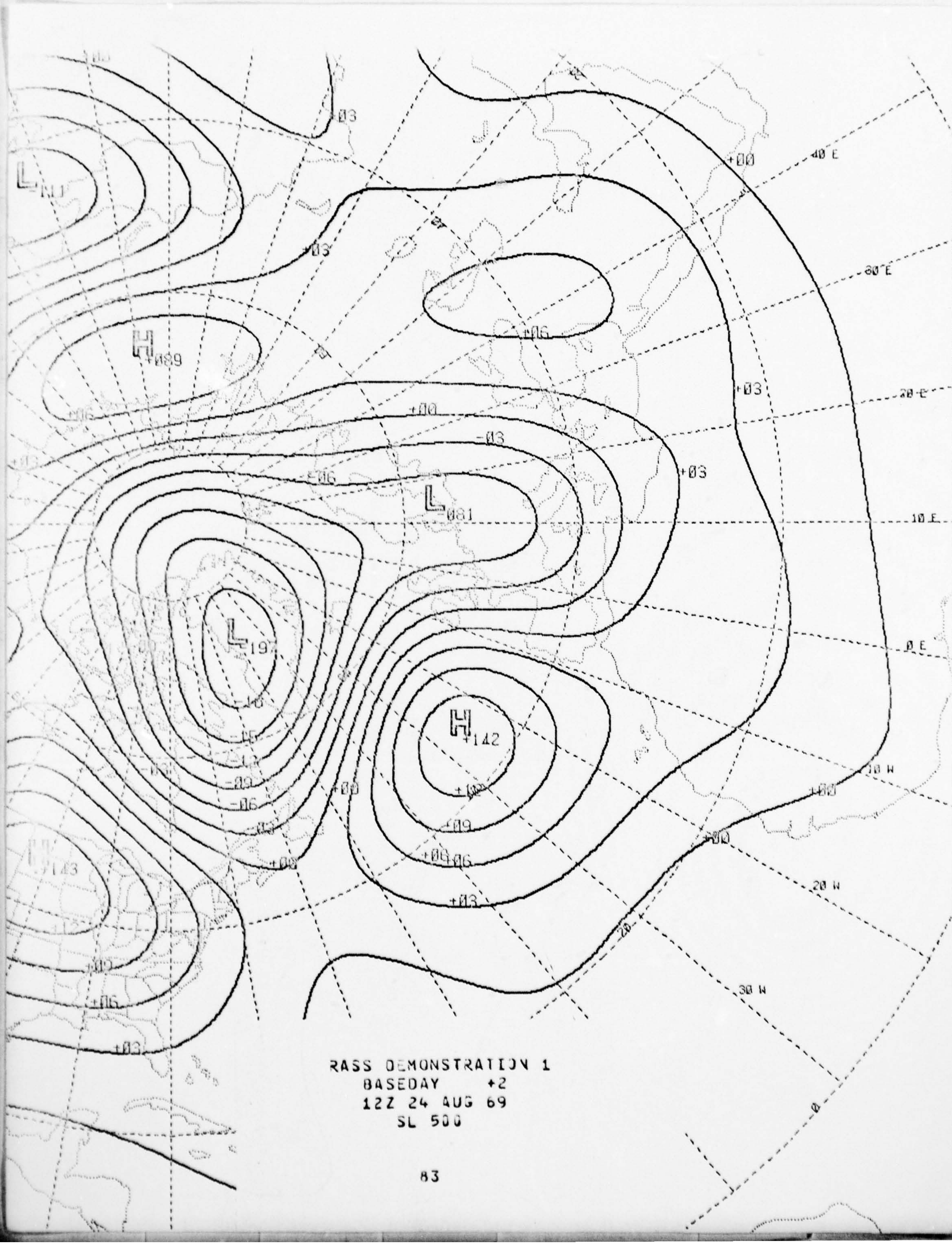
12Z 22 AUG 69
SL 500



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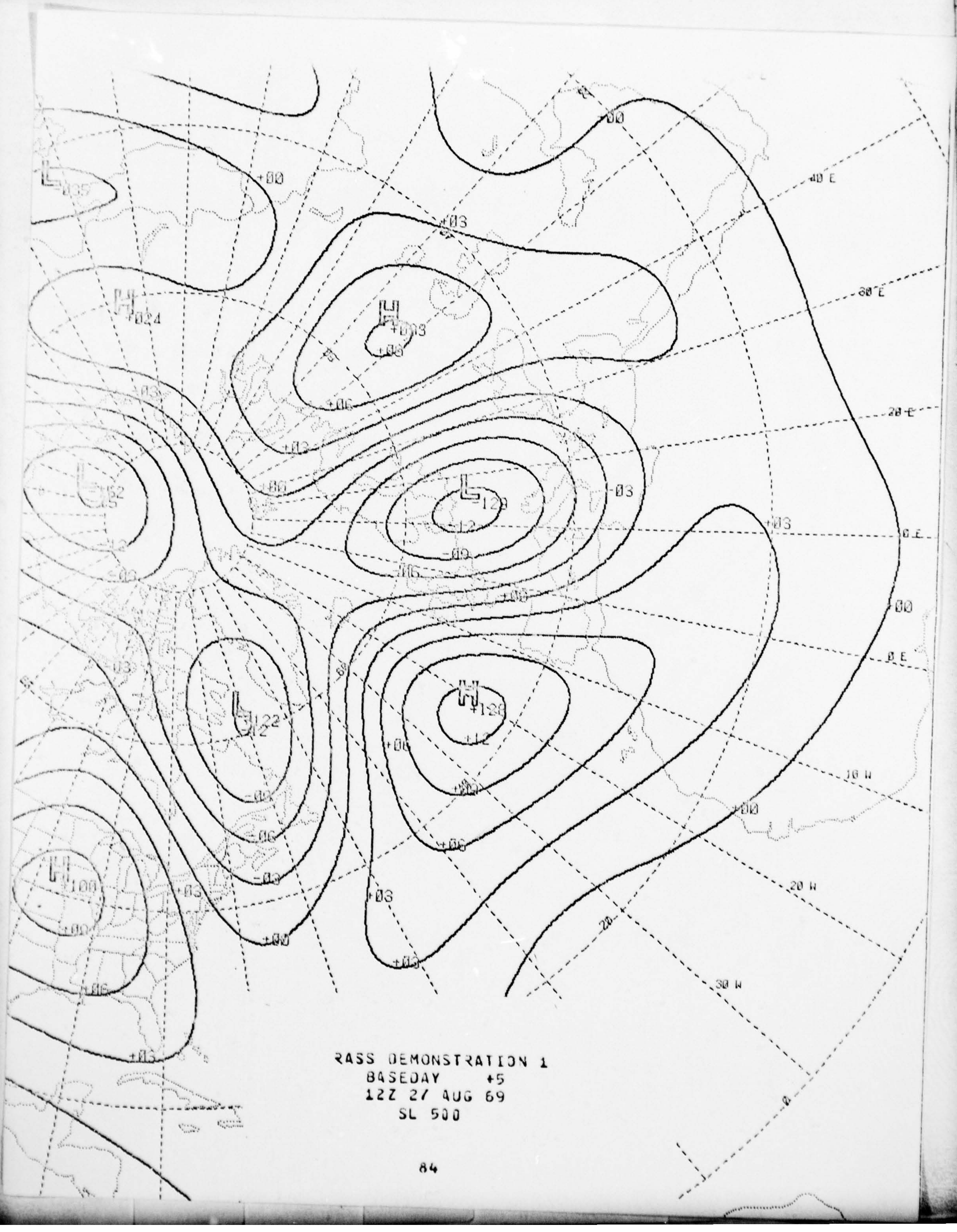

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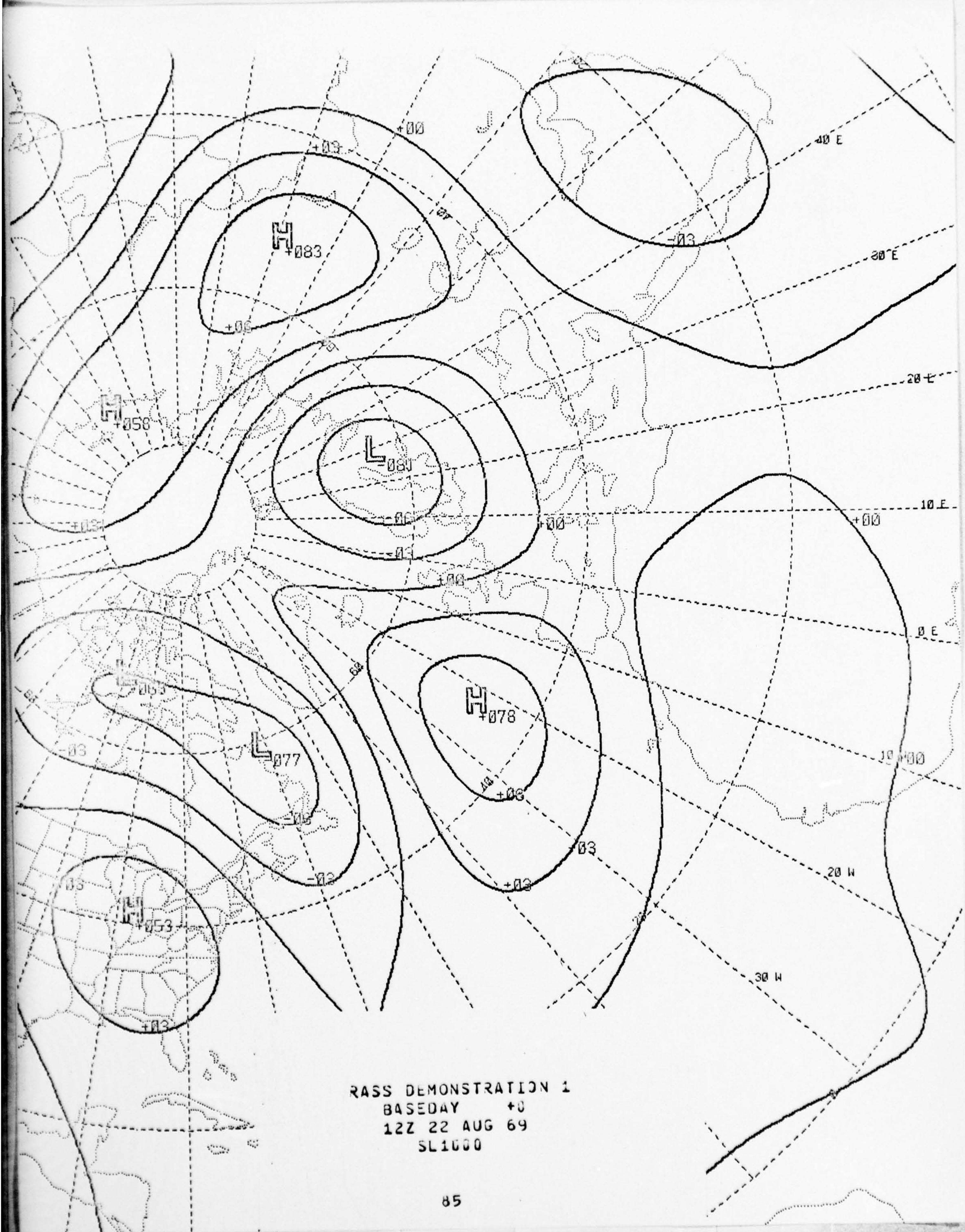
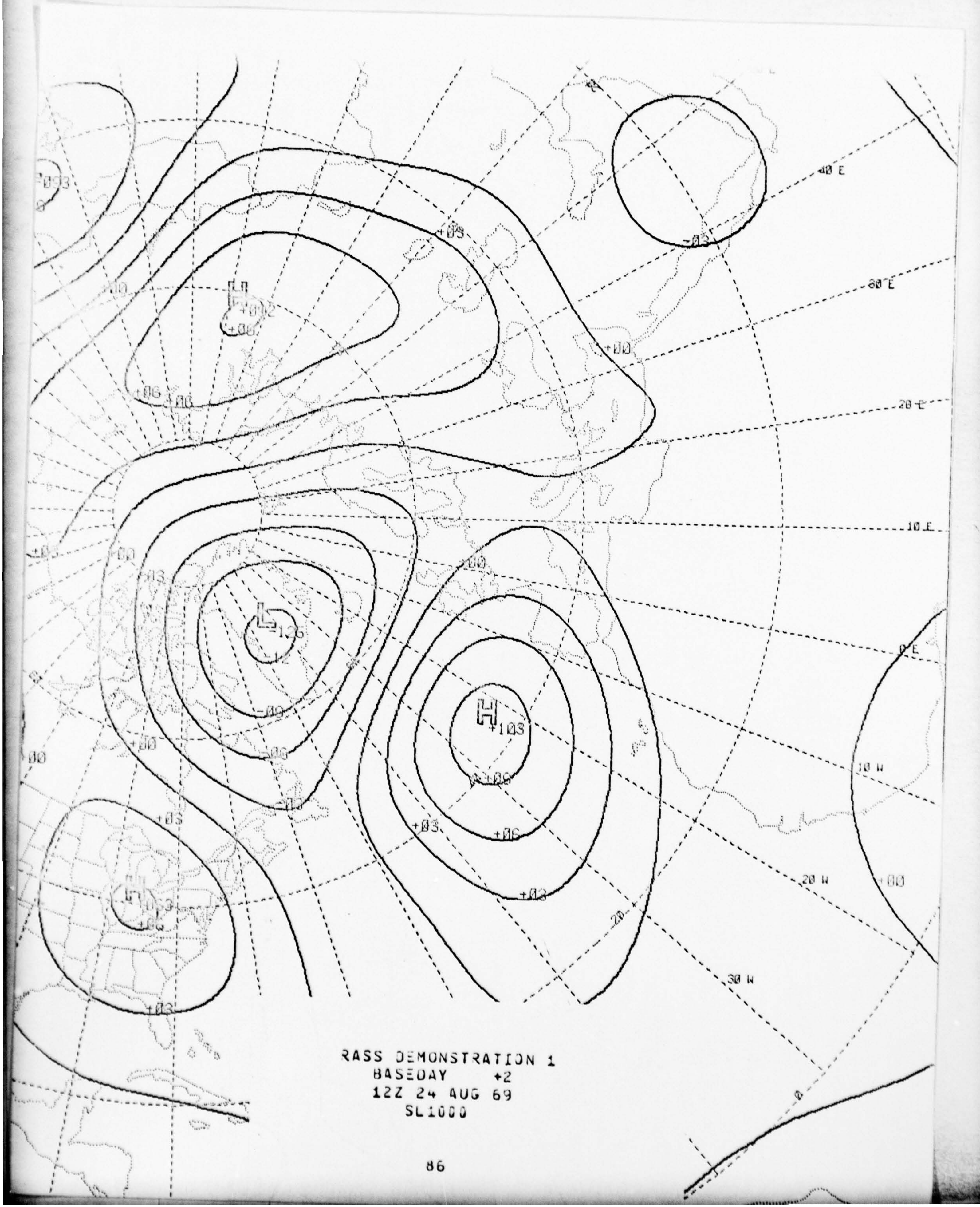
12Z 27 AUG 69
SL 500



+00
+03
40 E
30 E
20 E
10 E
0 E
20 W
30 W
H +083
+06
H +058
L -080
-06
-03
+00
H +078
L 077
L +063
H +053
-03
RASS DEMONSTRATION 1
BASEDAY +0
12Z 22 AUG 69
SL1000



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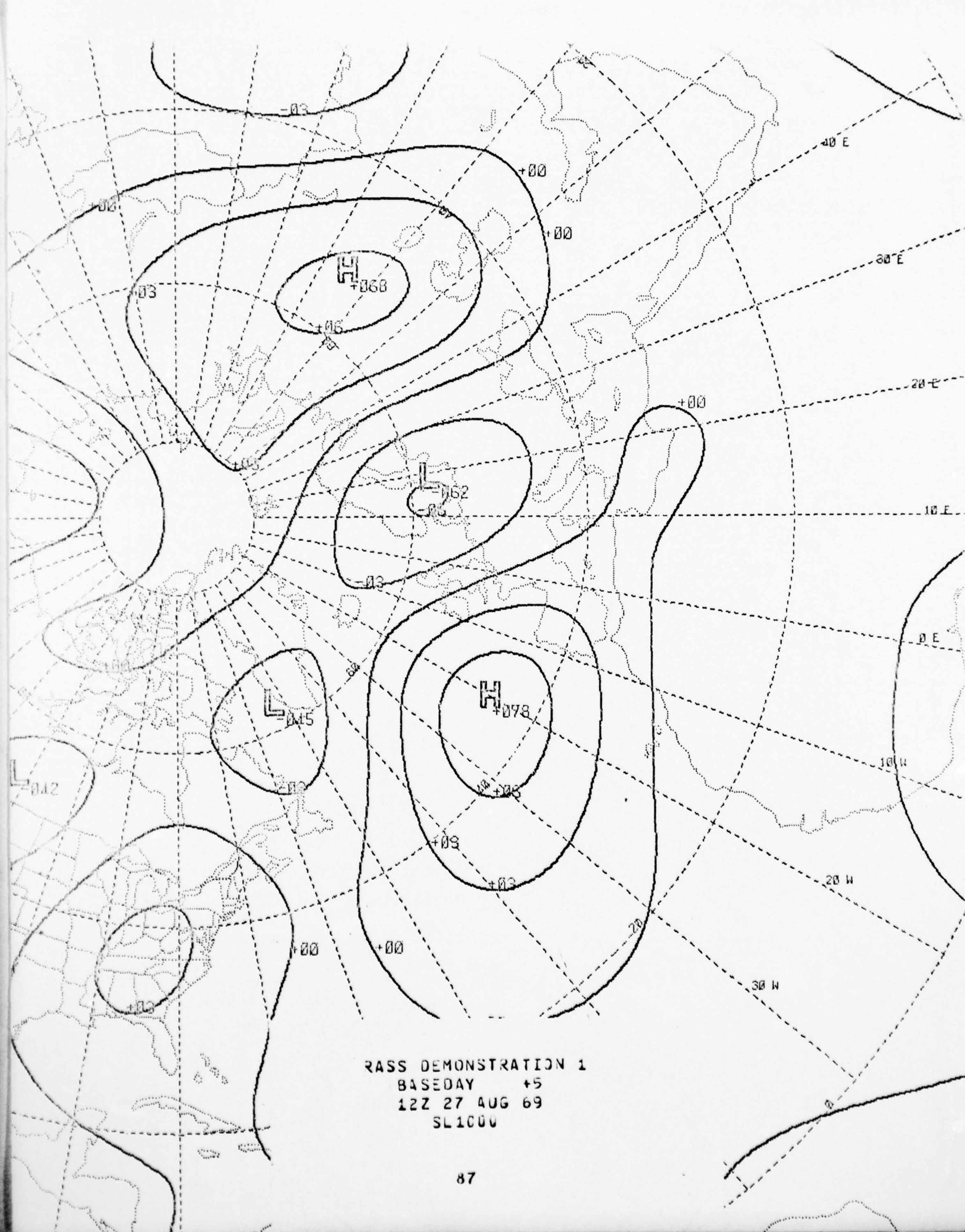

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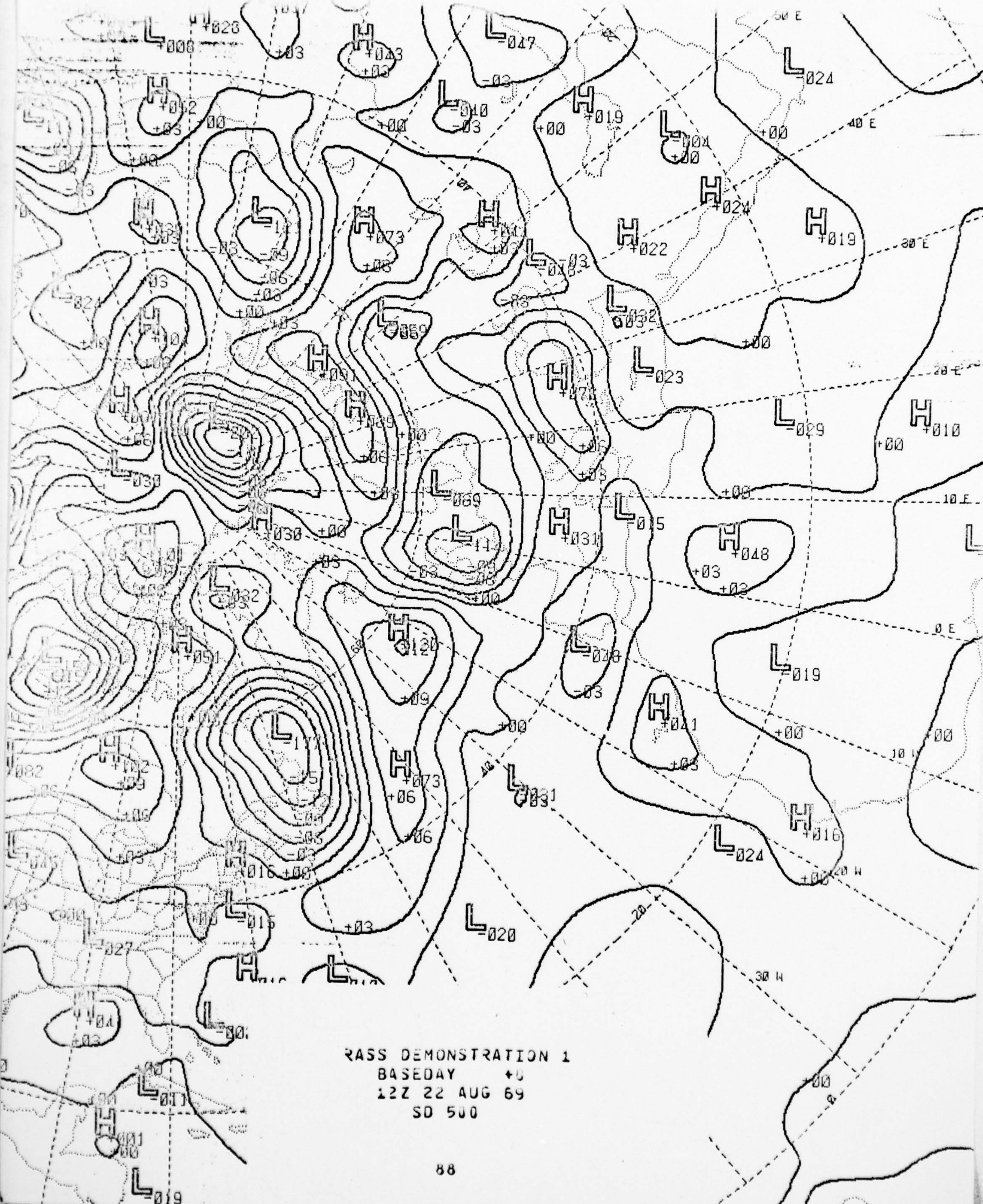

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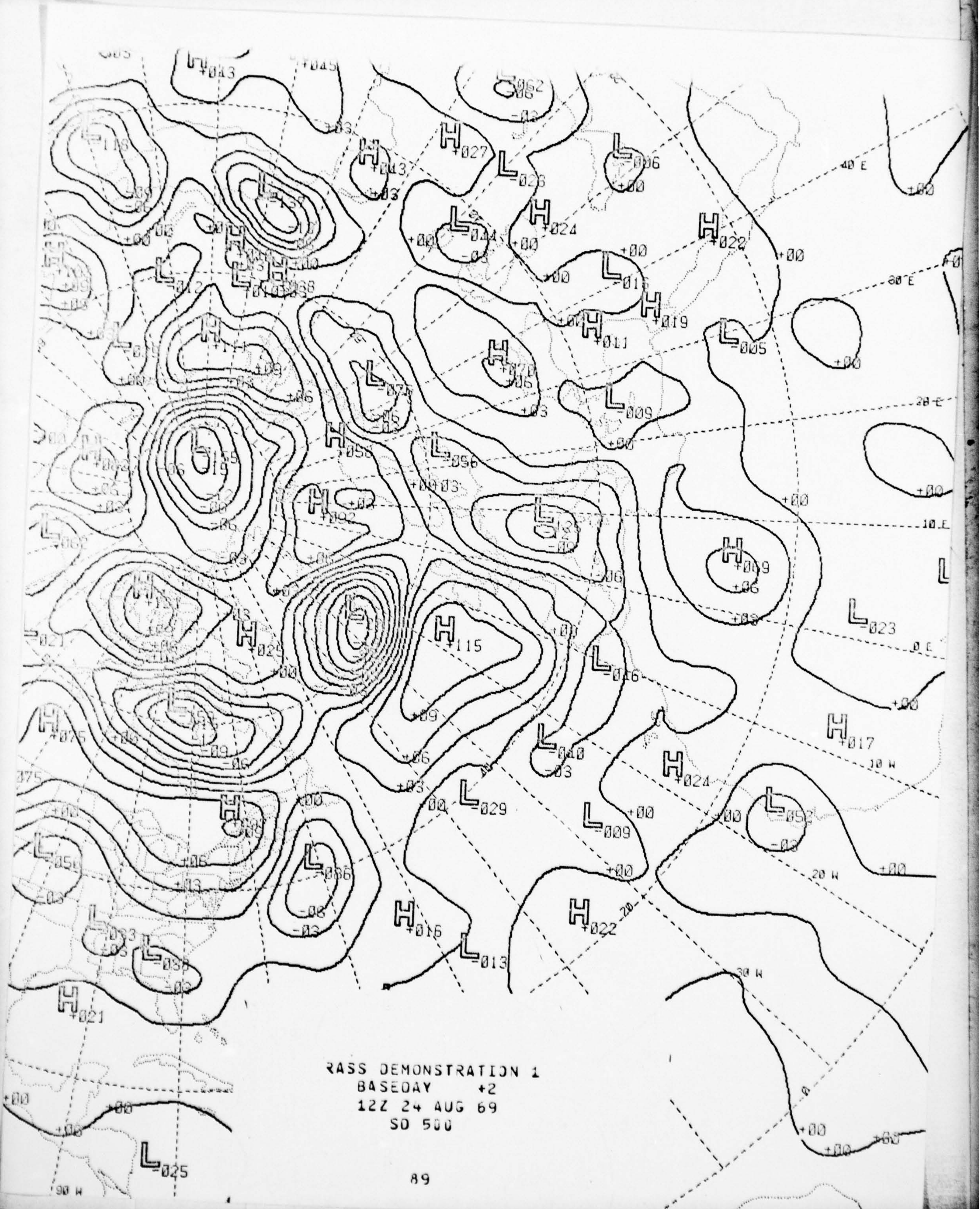

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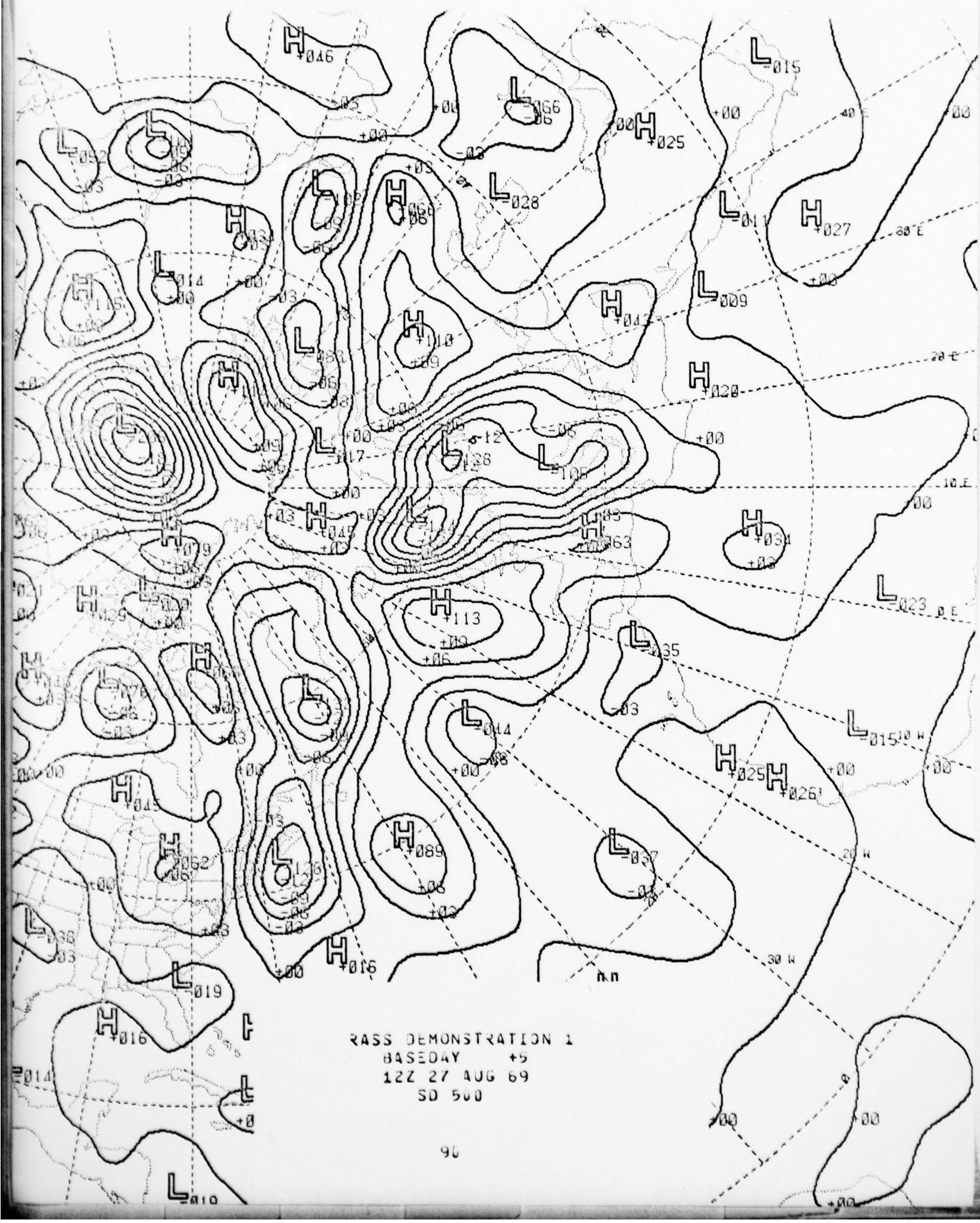

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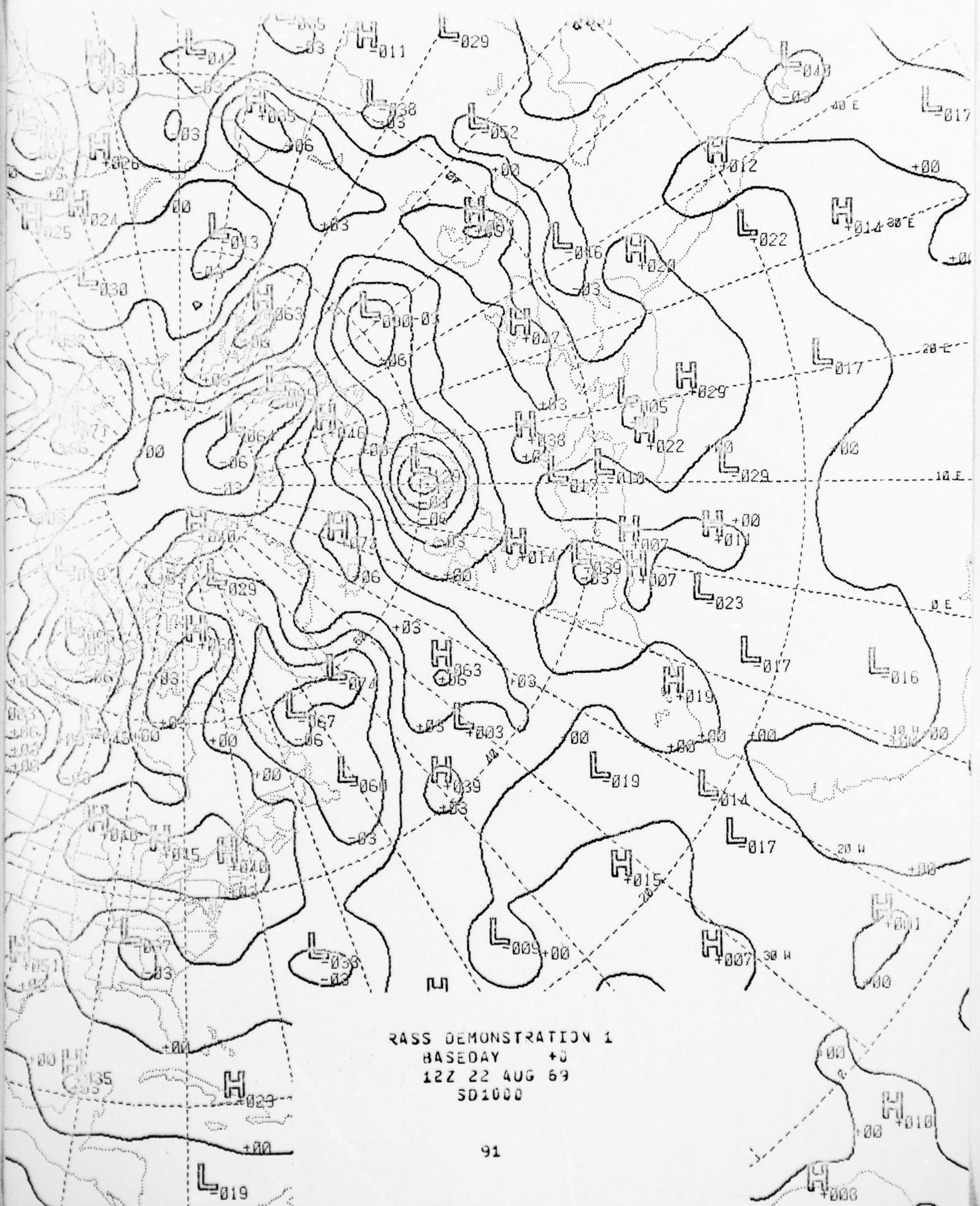

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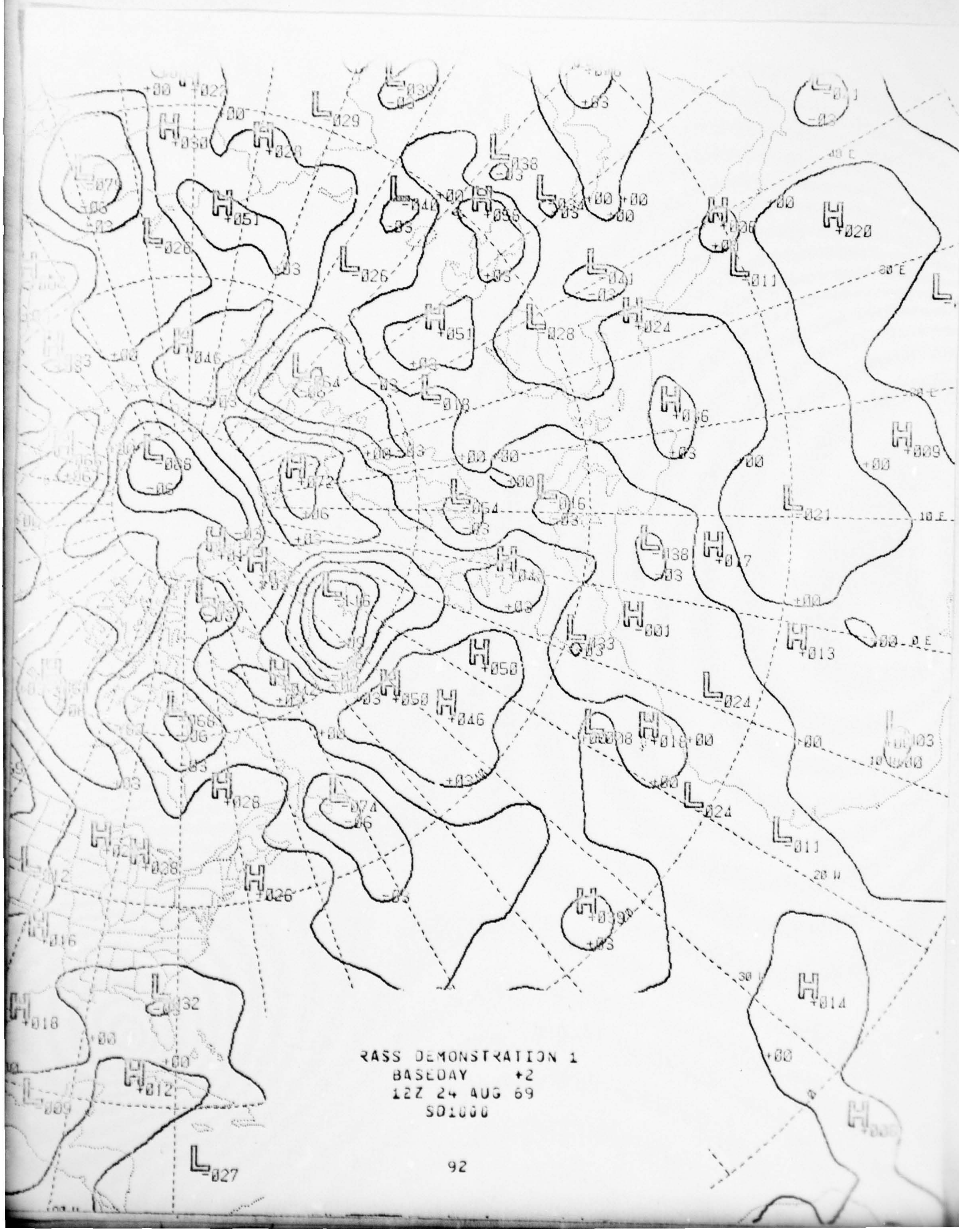

RASS DEMONSTRATION 1
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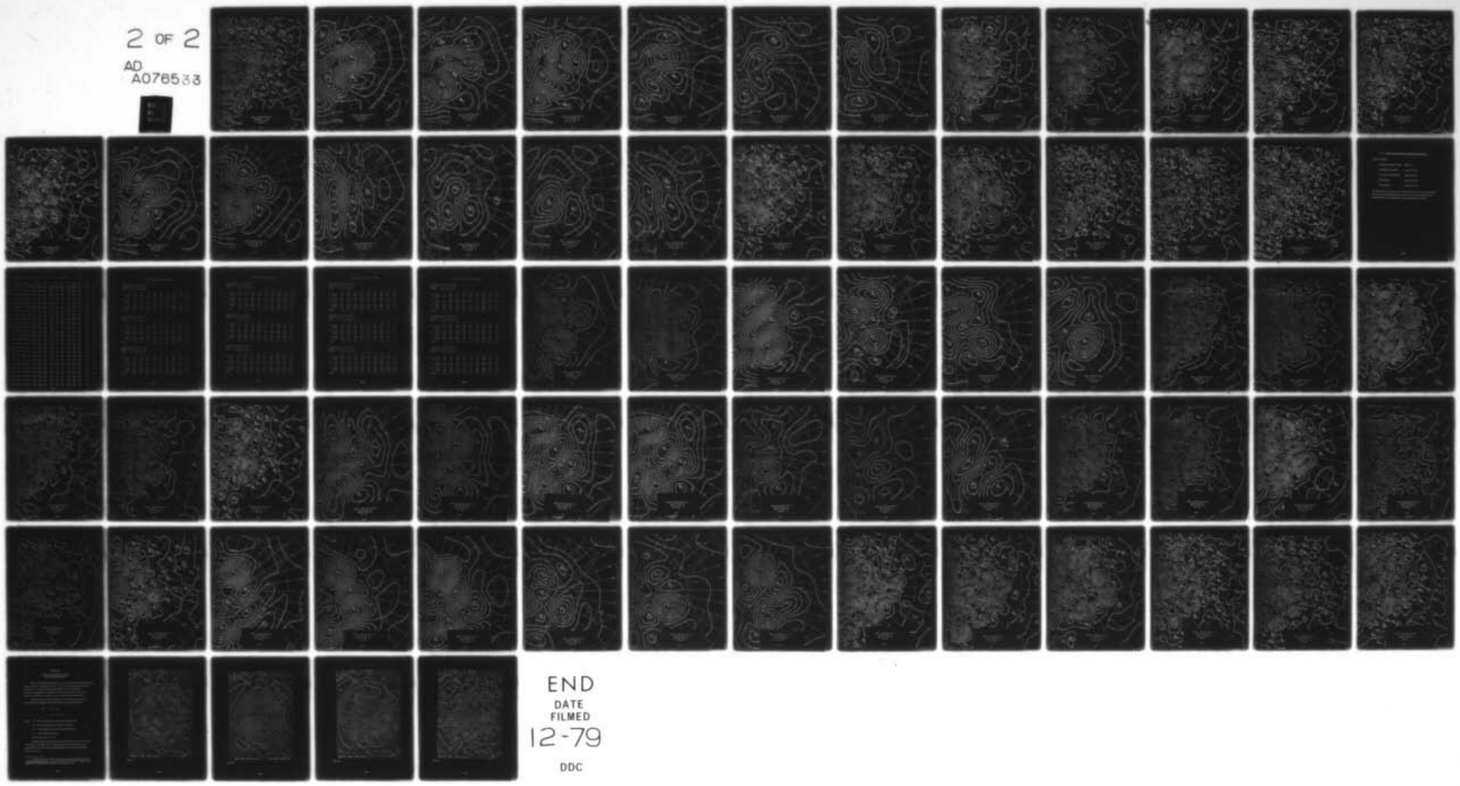
SD1000

AD-A076 533 METEOROLOGY INTERNATIONAL INC MONTEREY CALIF F/G 4/2
TECHNICAL DESCRIPTION OF THE RAPID ANALOGUE SELECTION SYSTEM IN--ETC(U)
JUN 77 F C CATON, M M HOLL, M J CUMING N00228-76-C-3189
UNCLASSIFIED MII-M-222 NL

2 OF 2

AD
A076533



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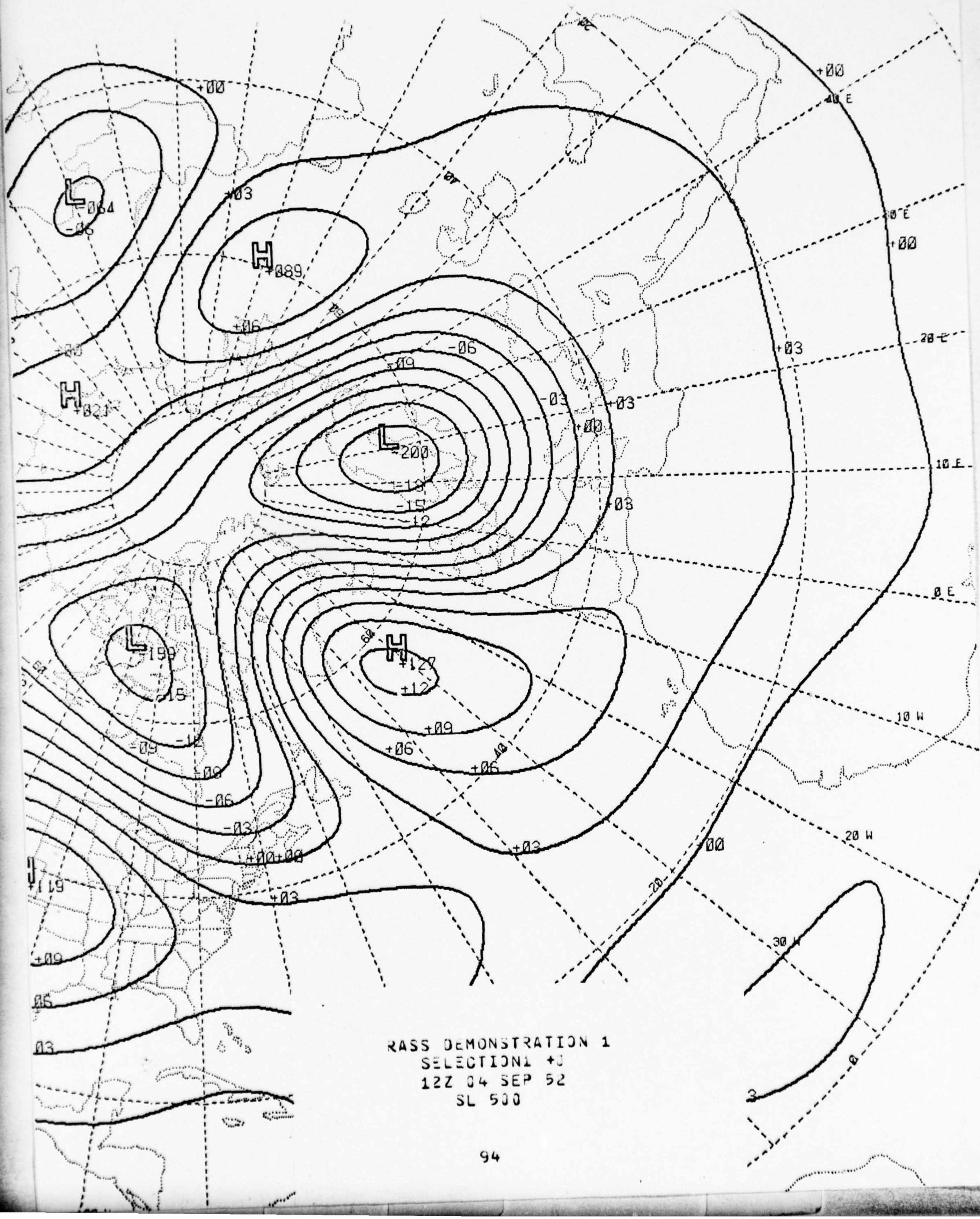

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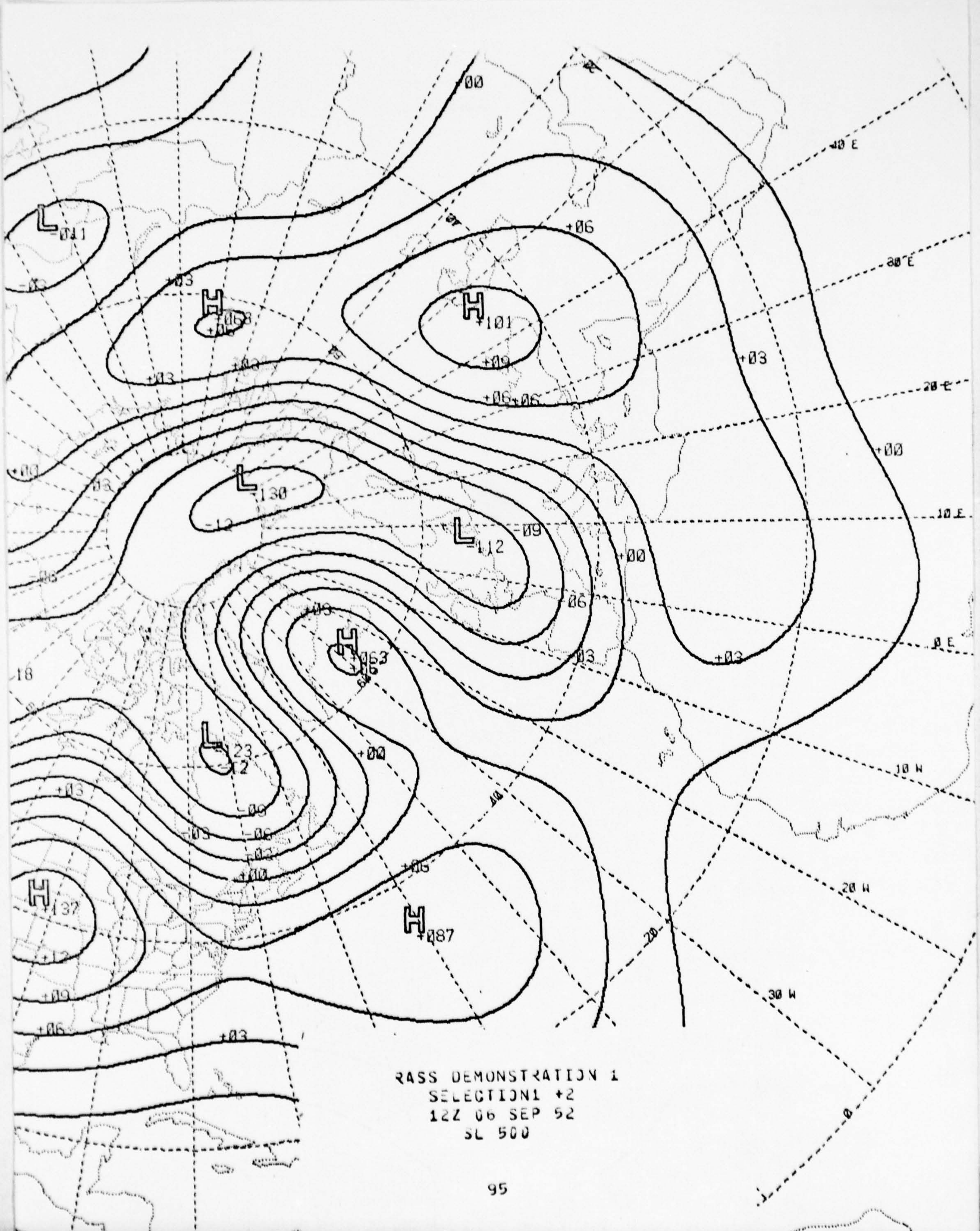

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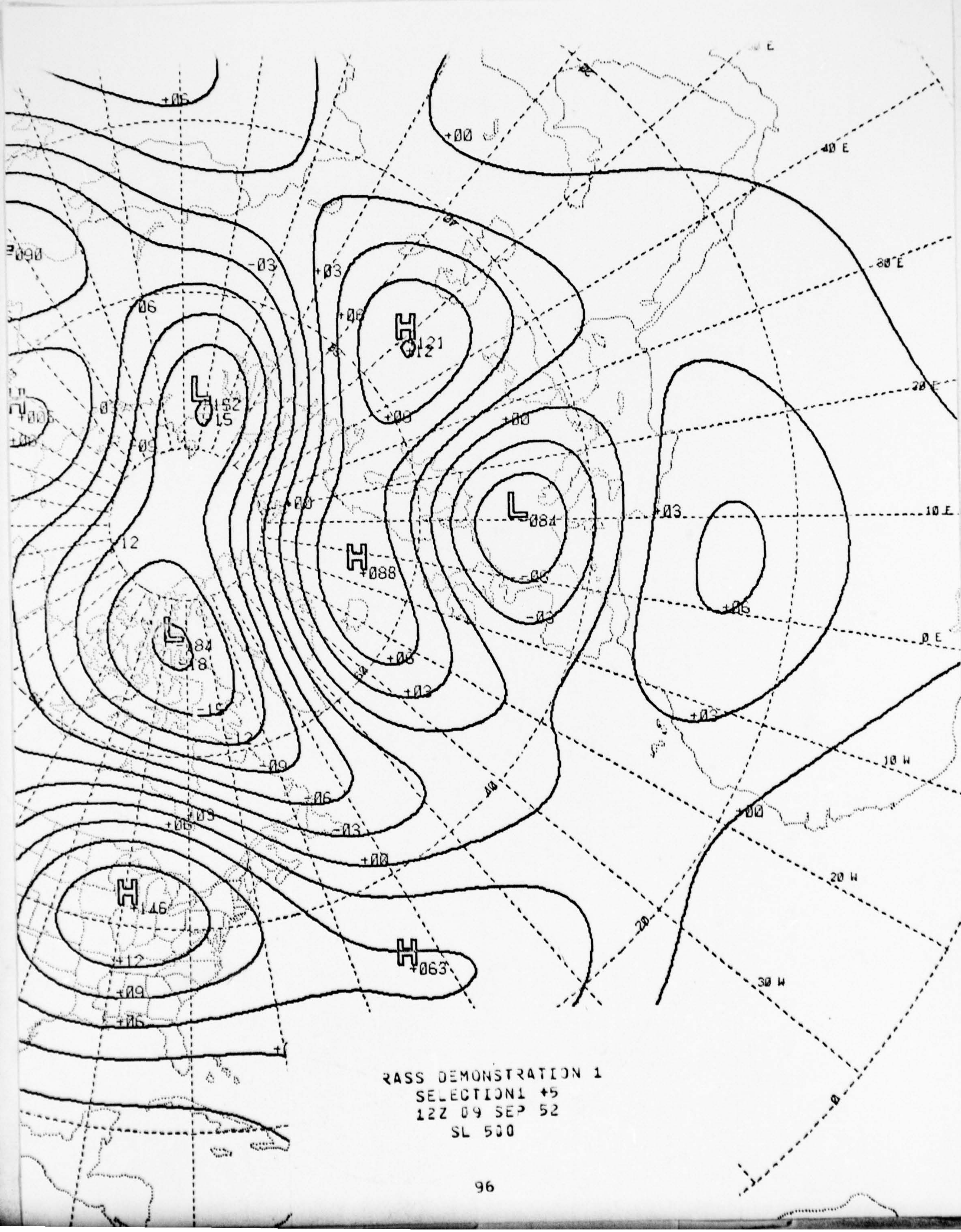

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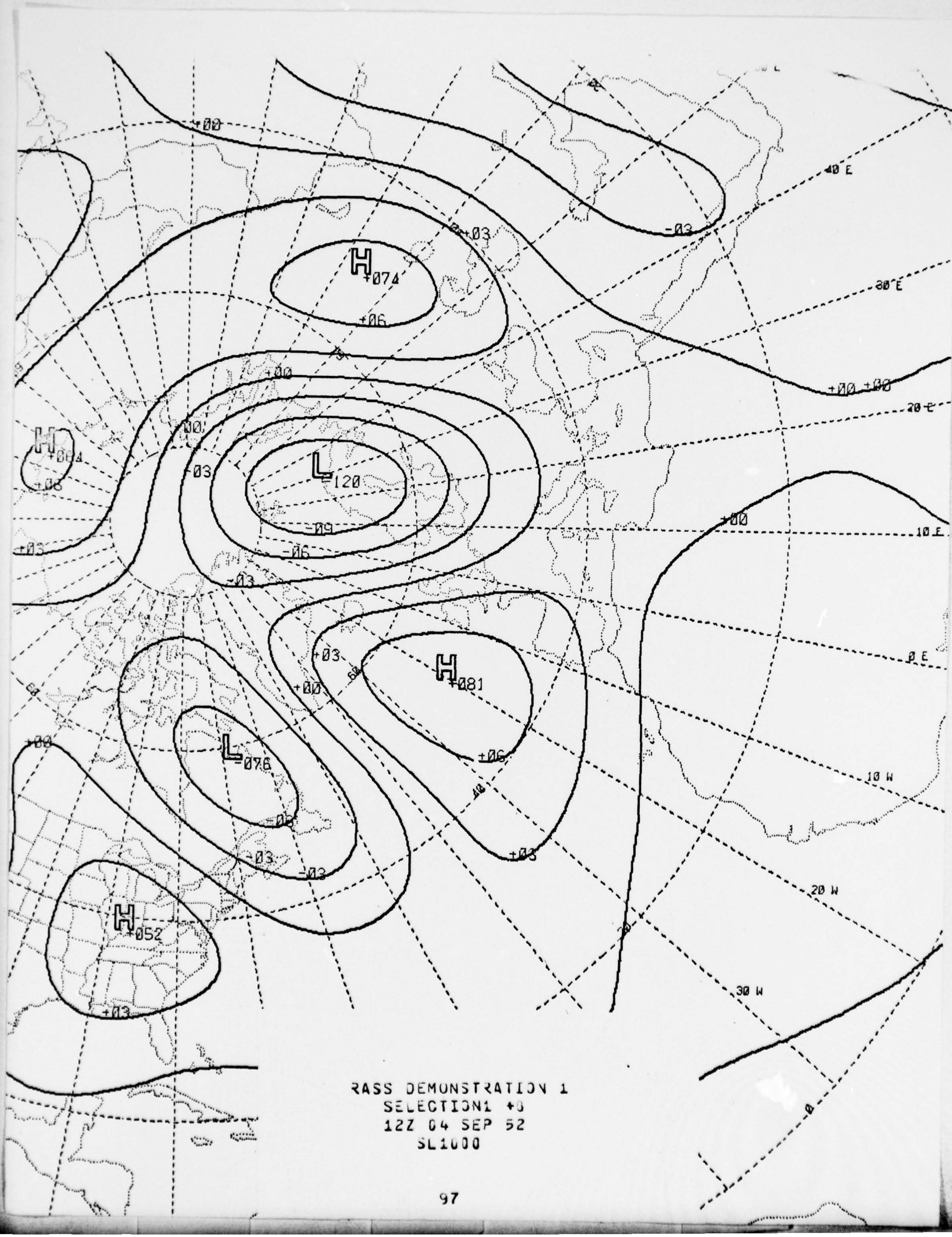

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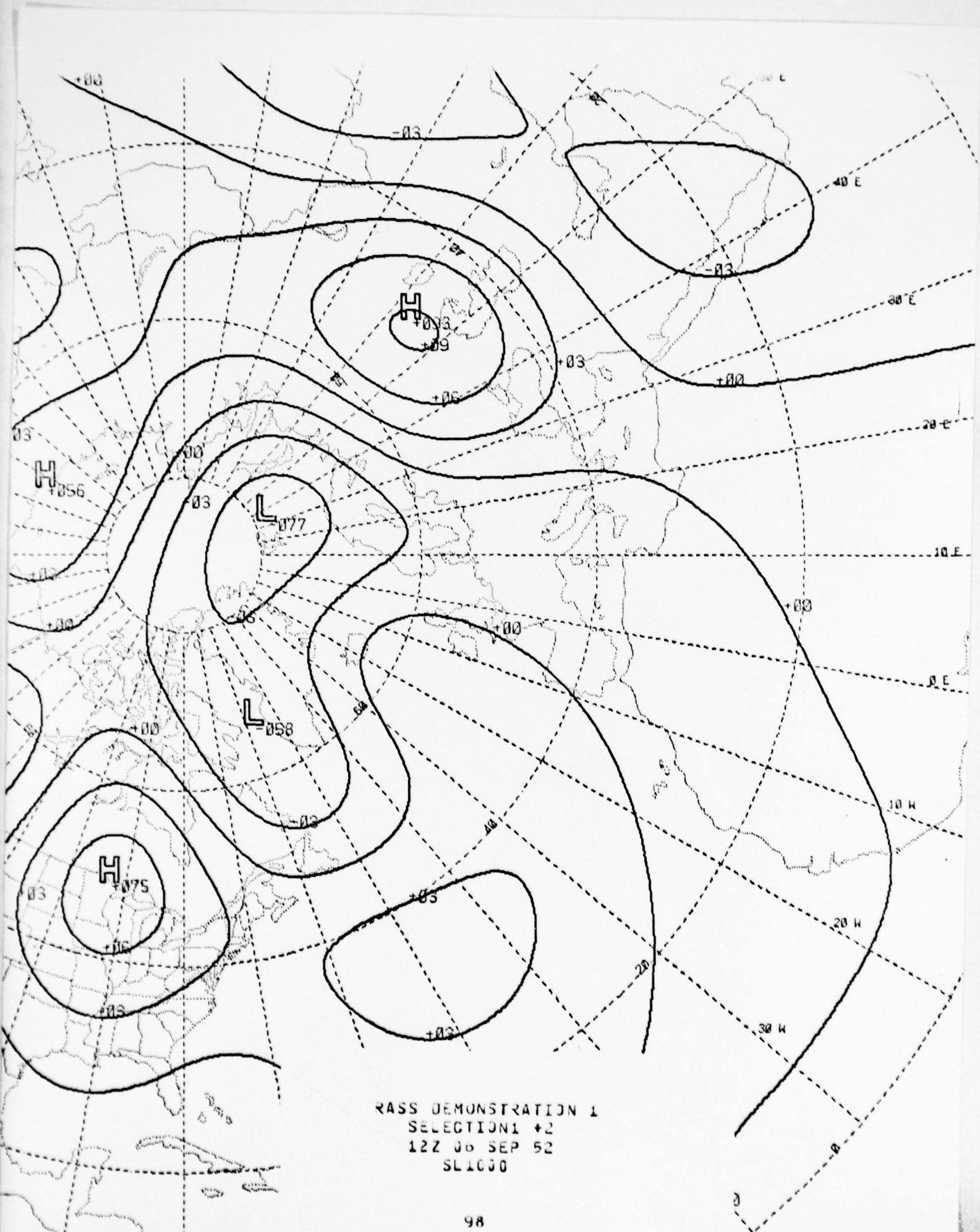

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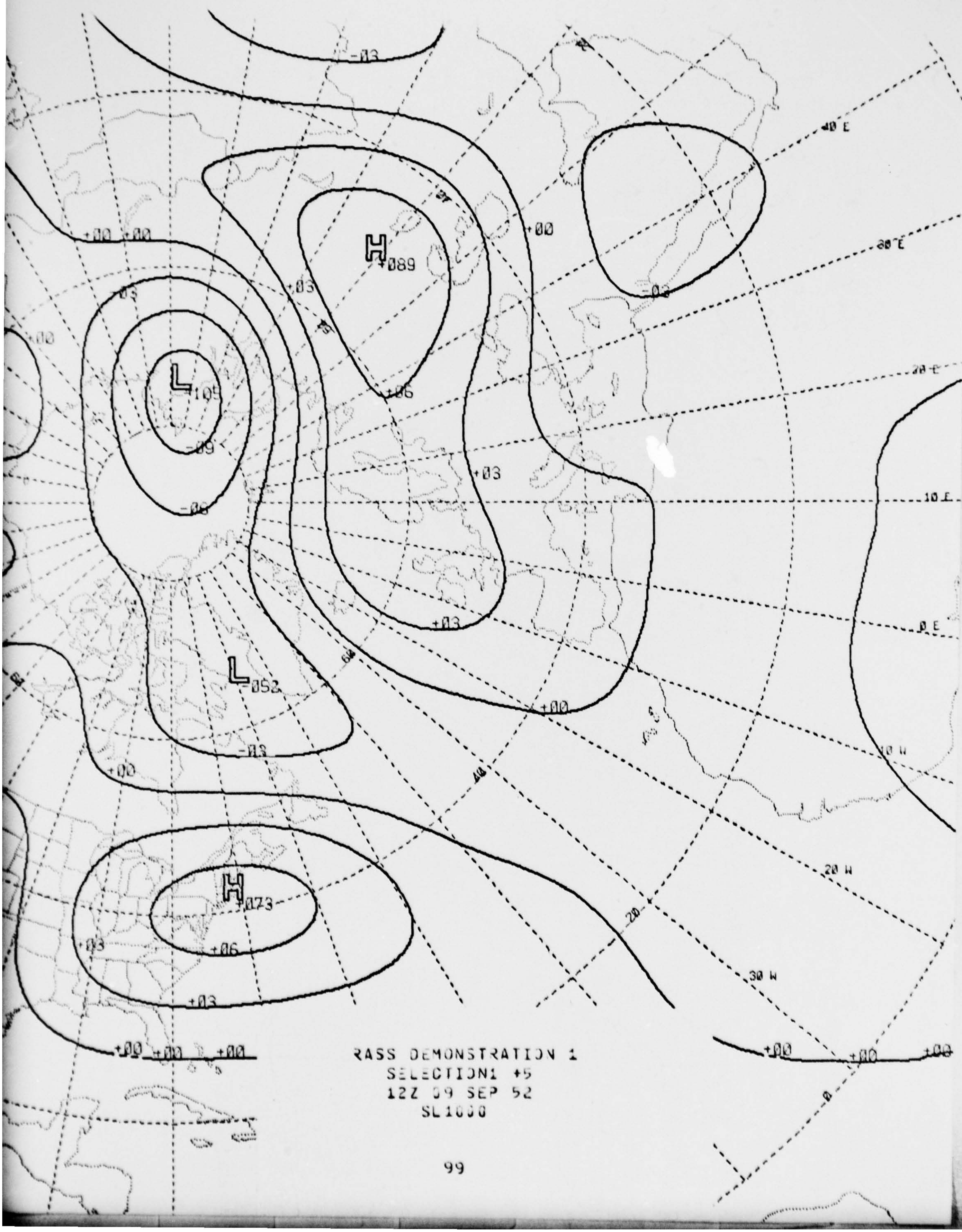

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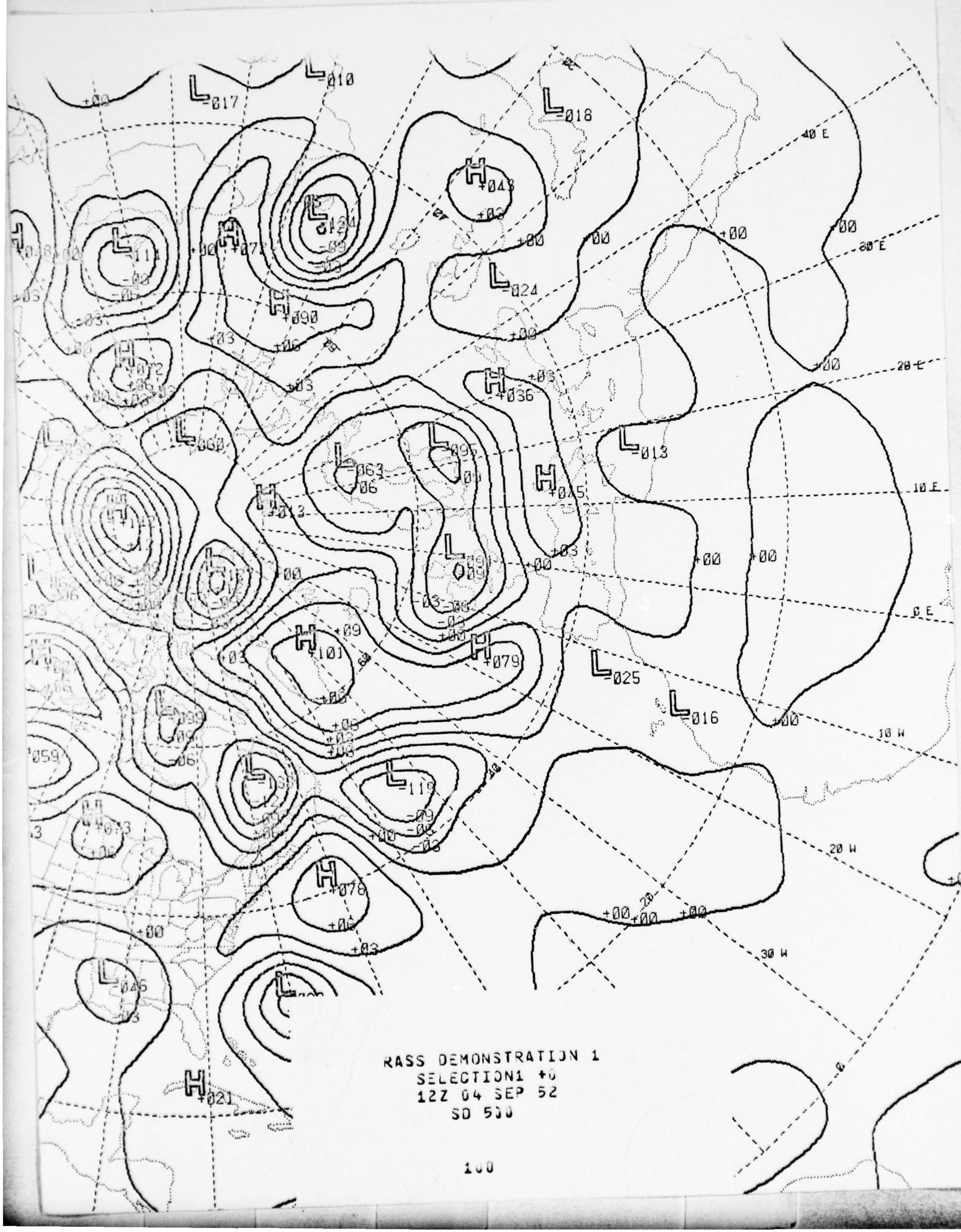

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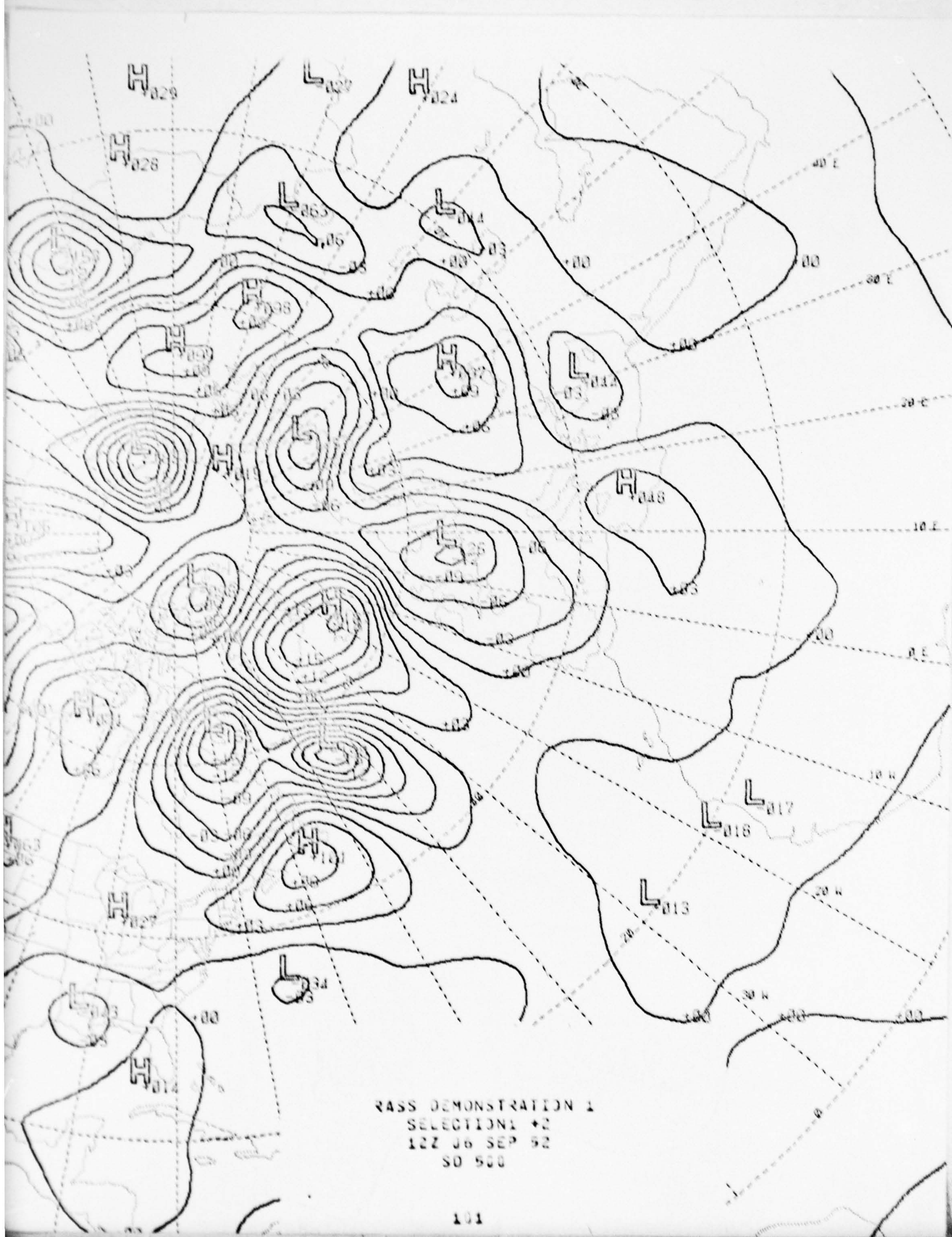

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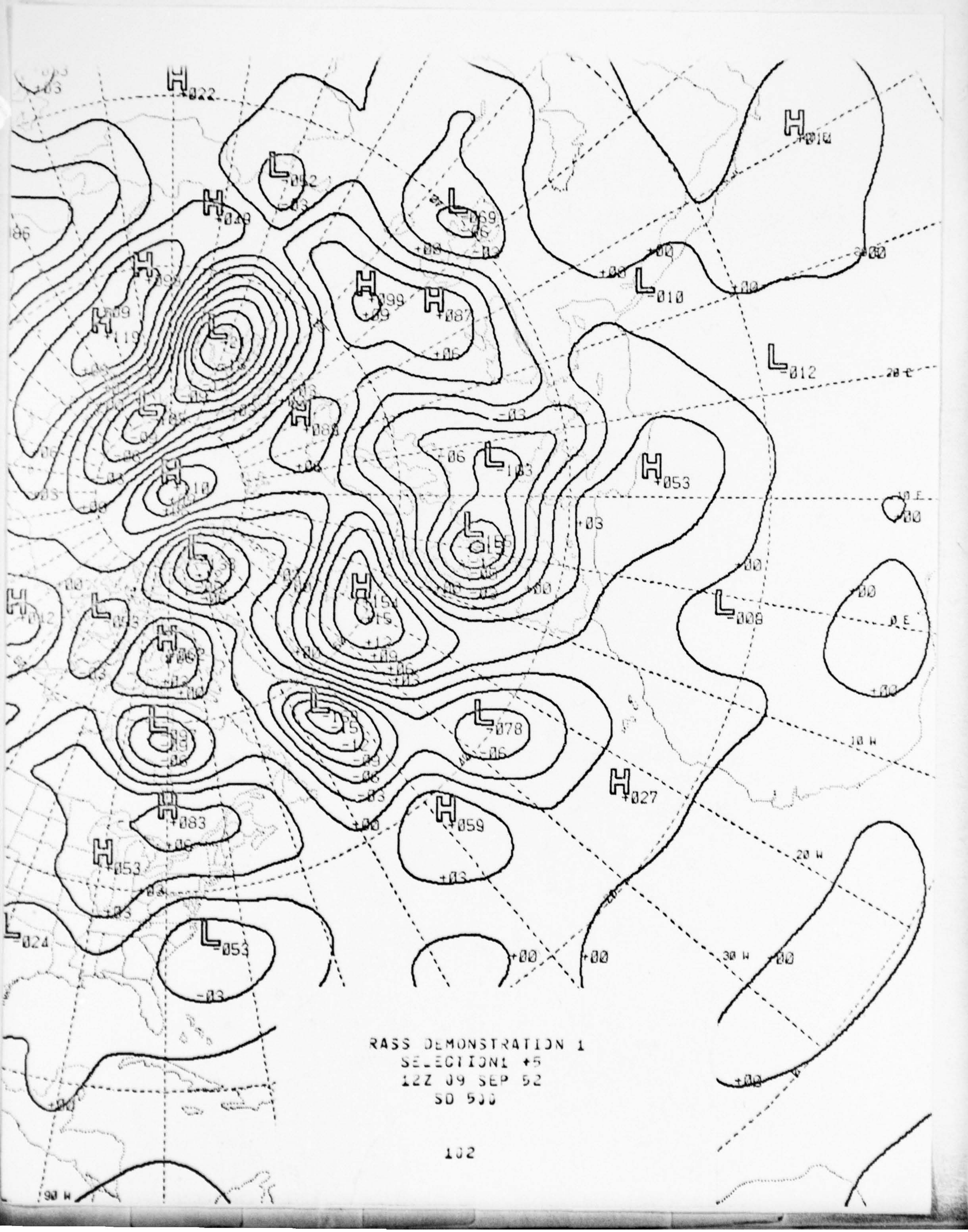

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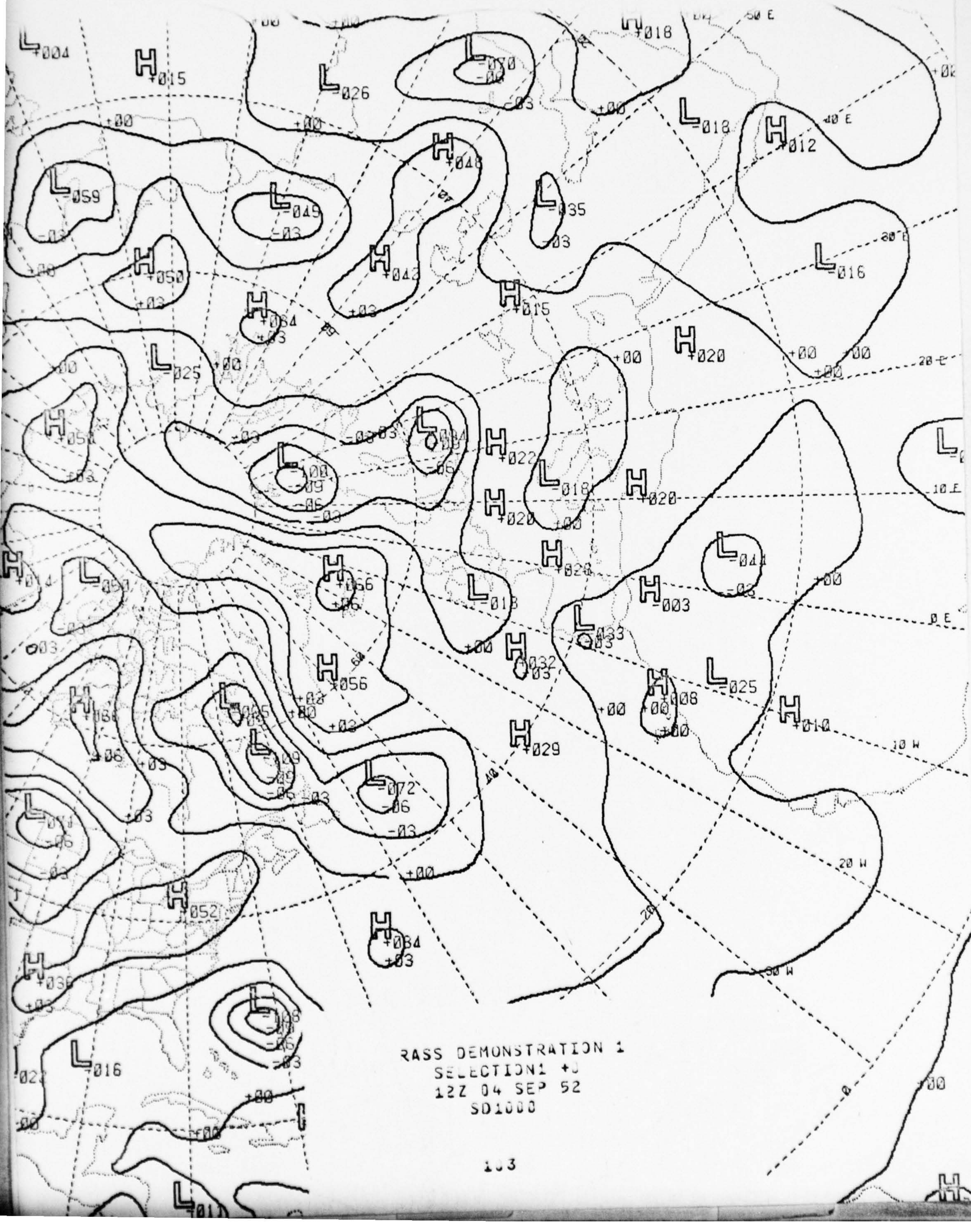

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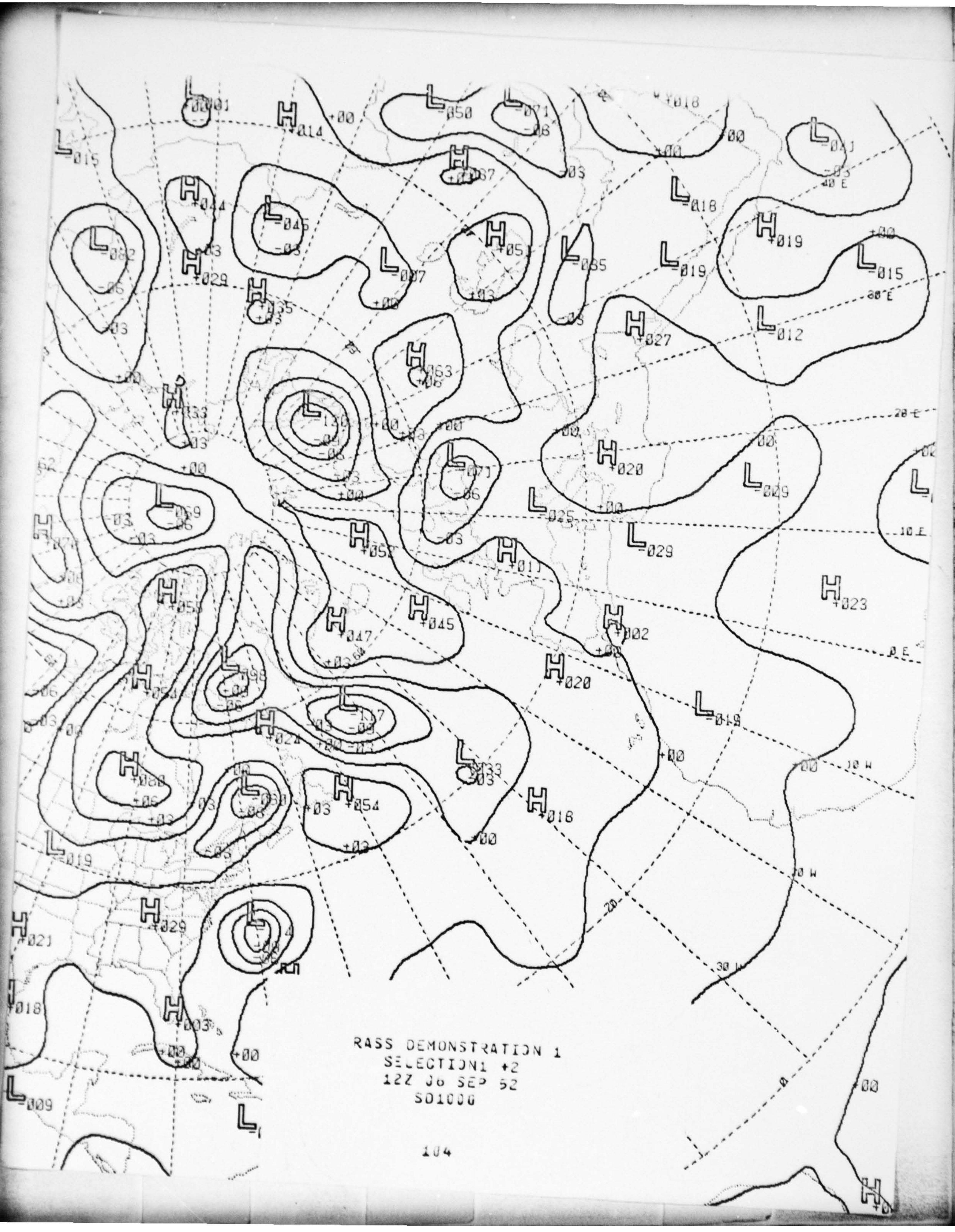
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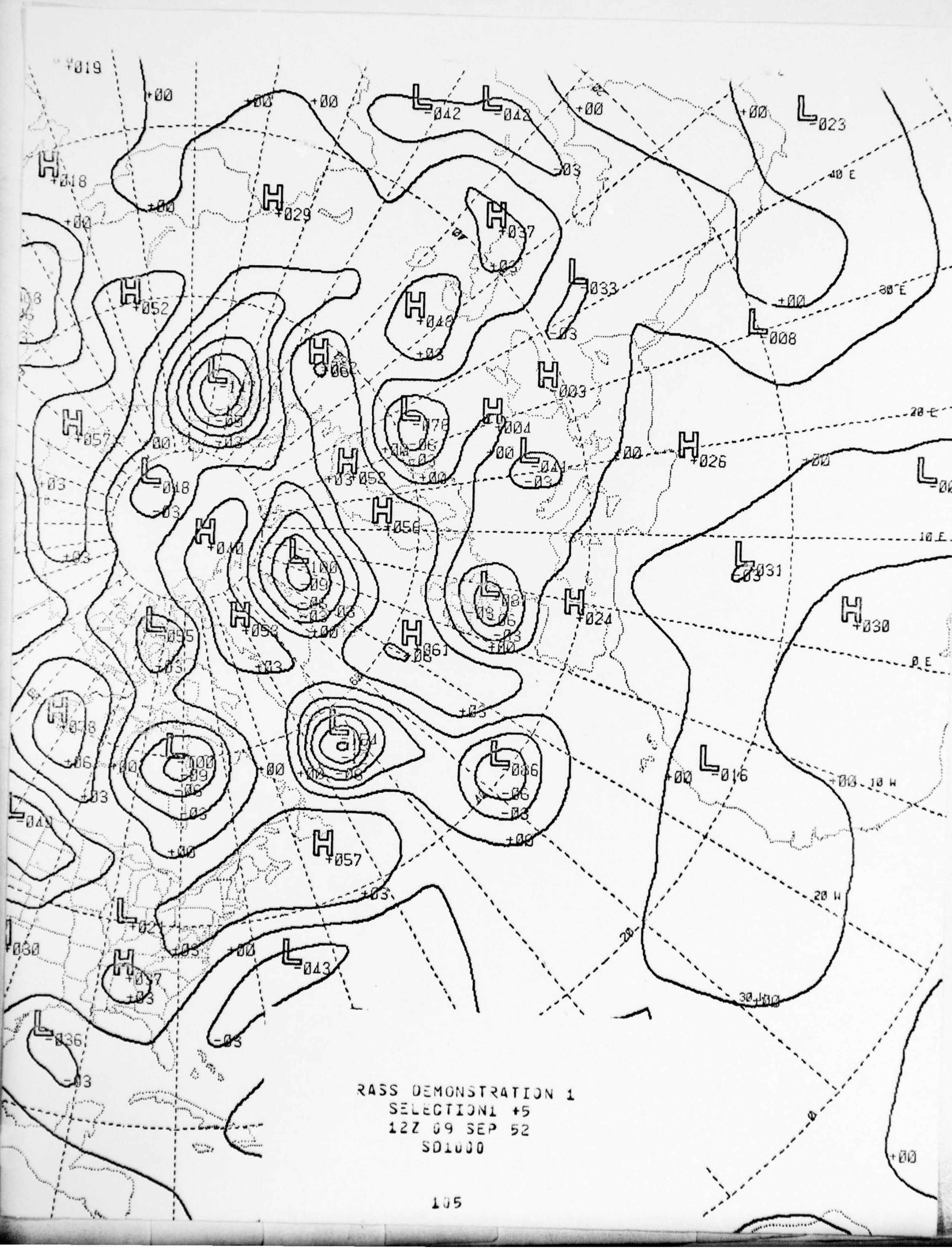

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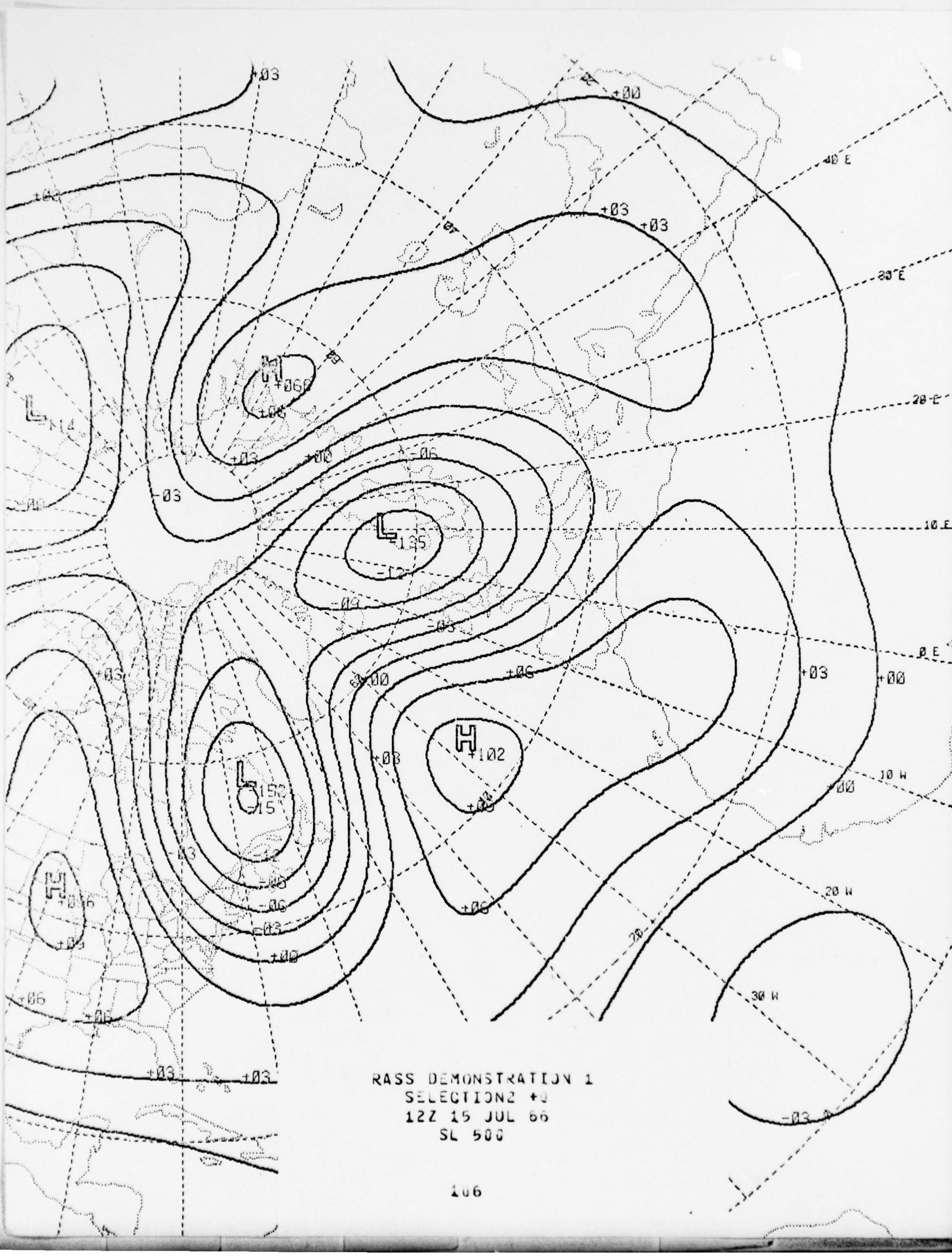

RASS DEMONSTRATION 1
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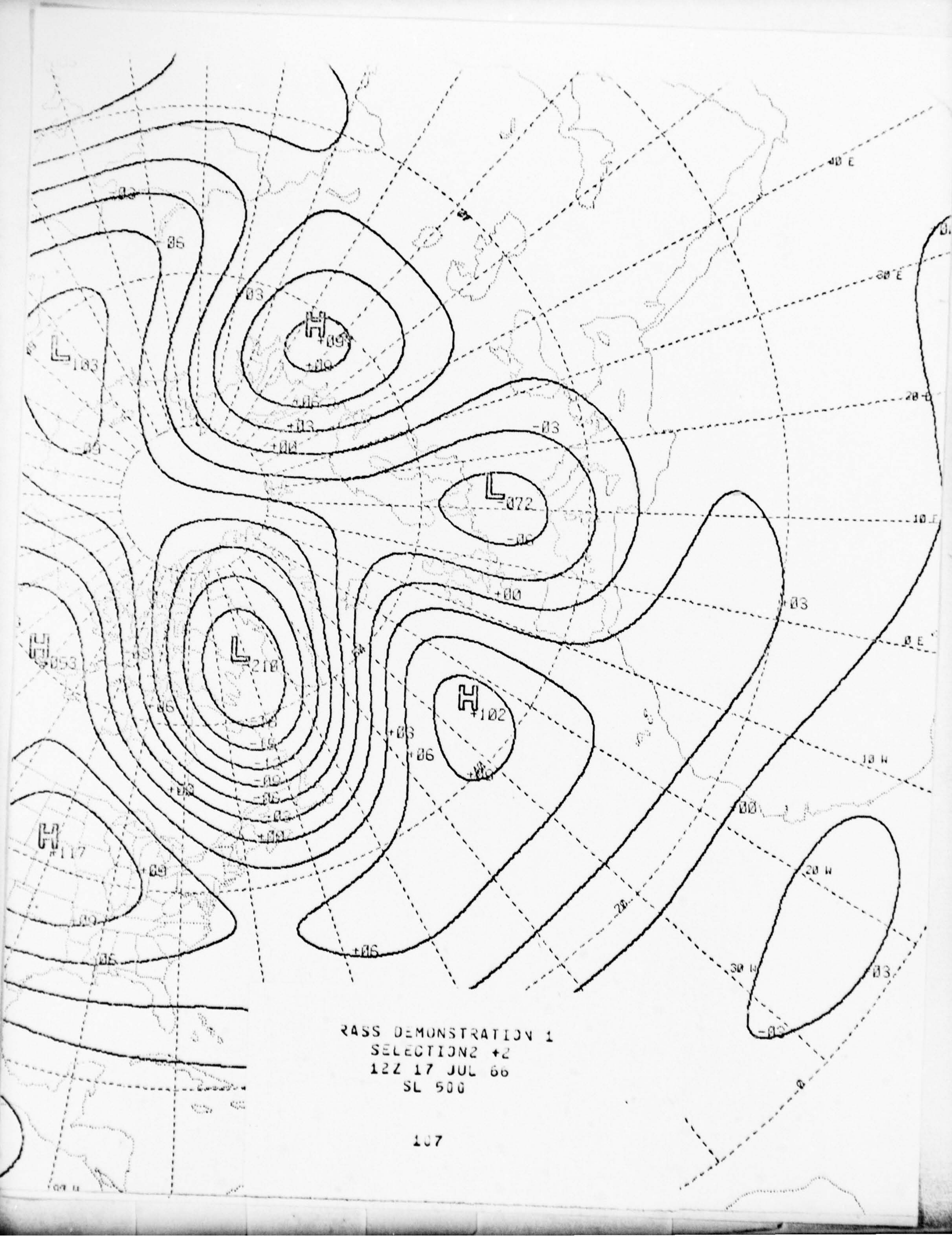
12Z 15 JUL 66
SL 500



RASS DEMONSTRATION 1
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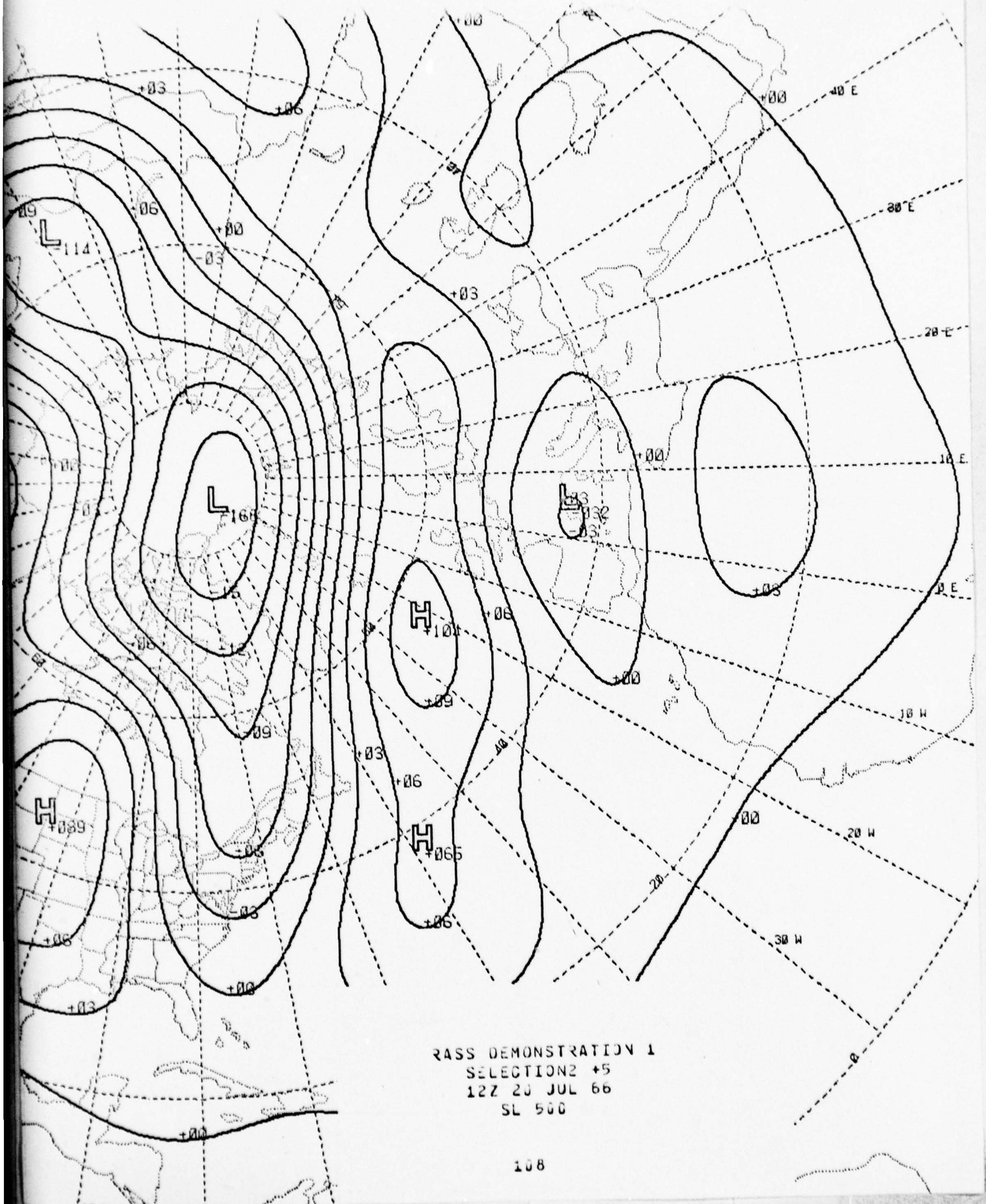

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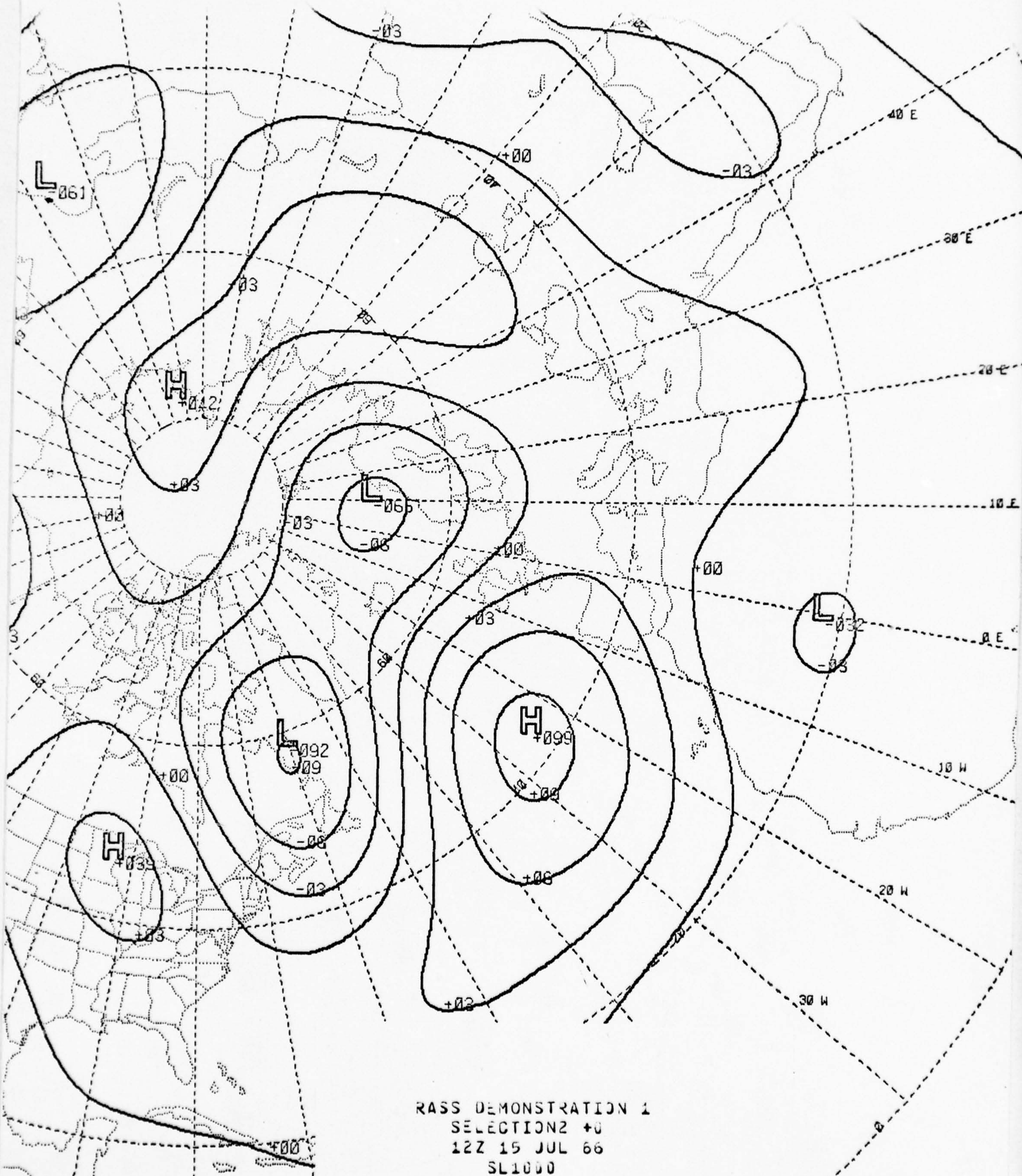

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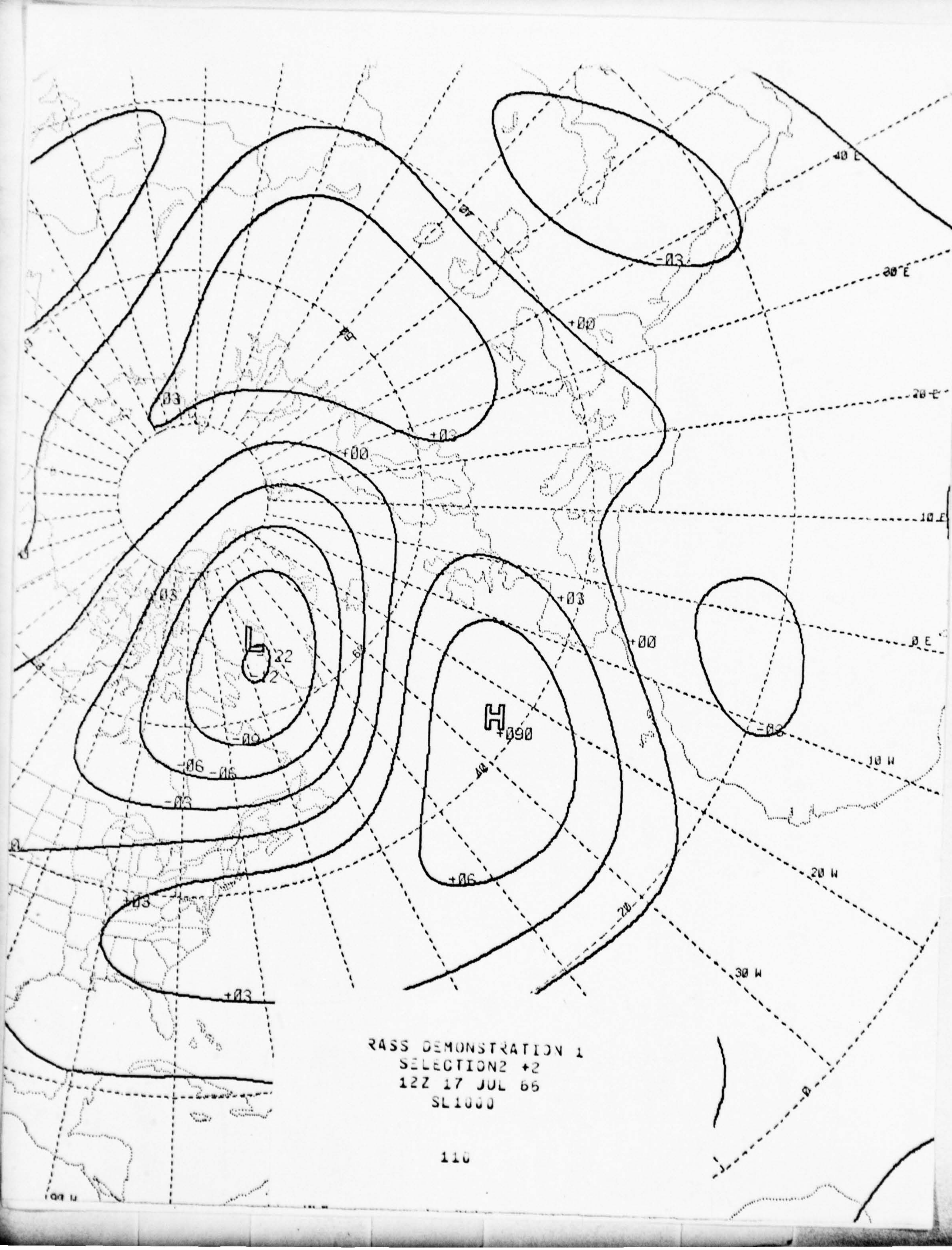

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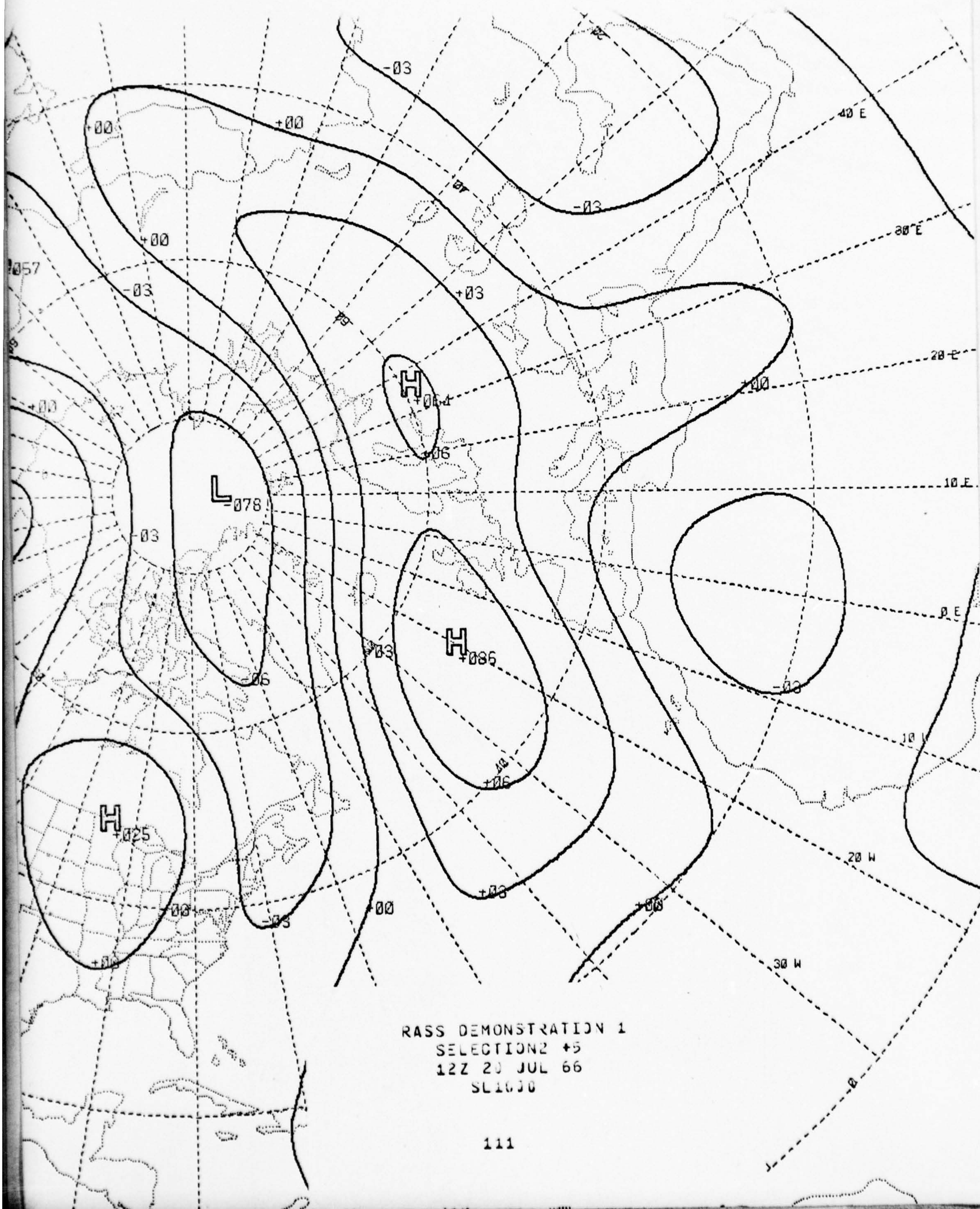

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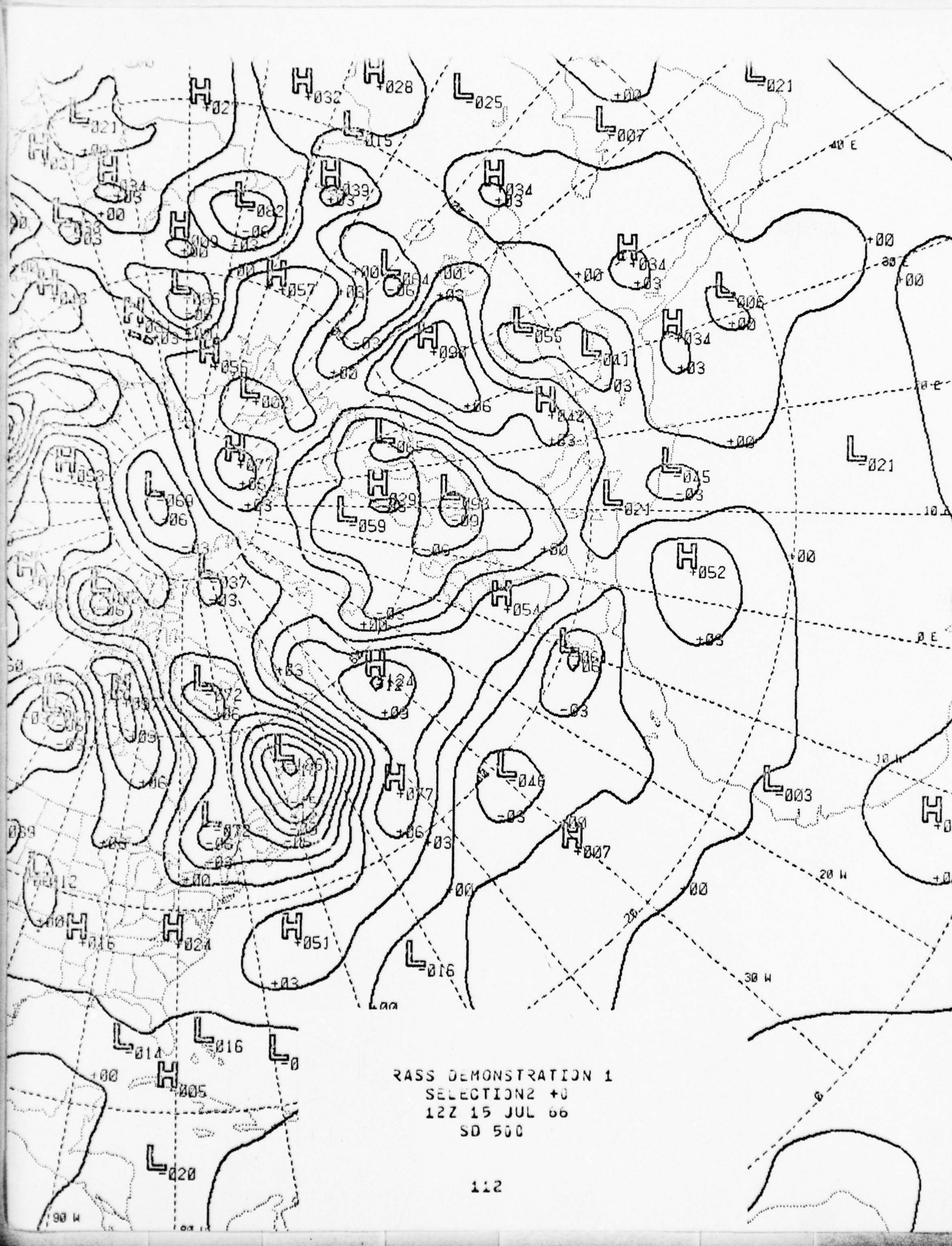

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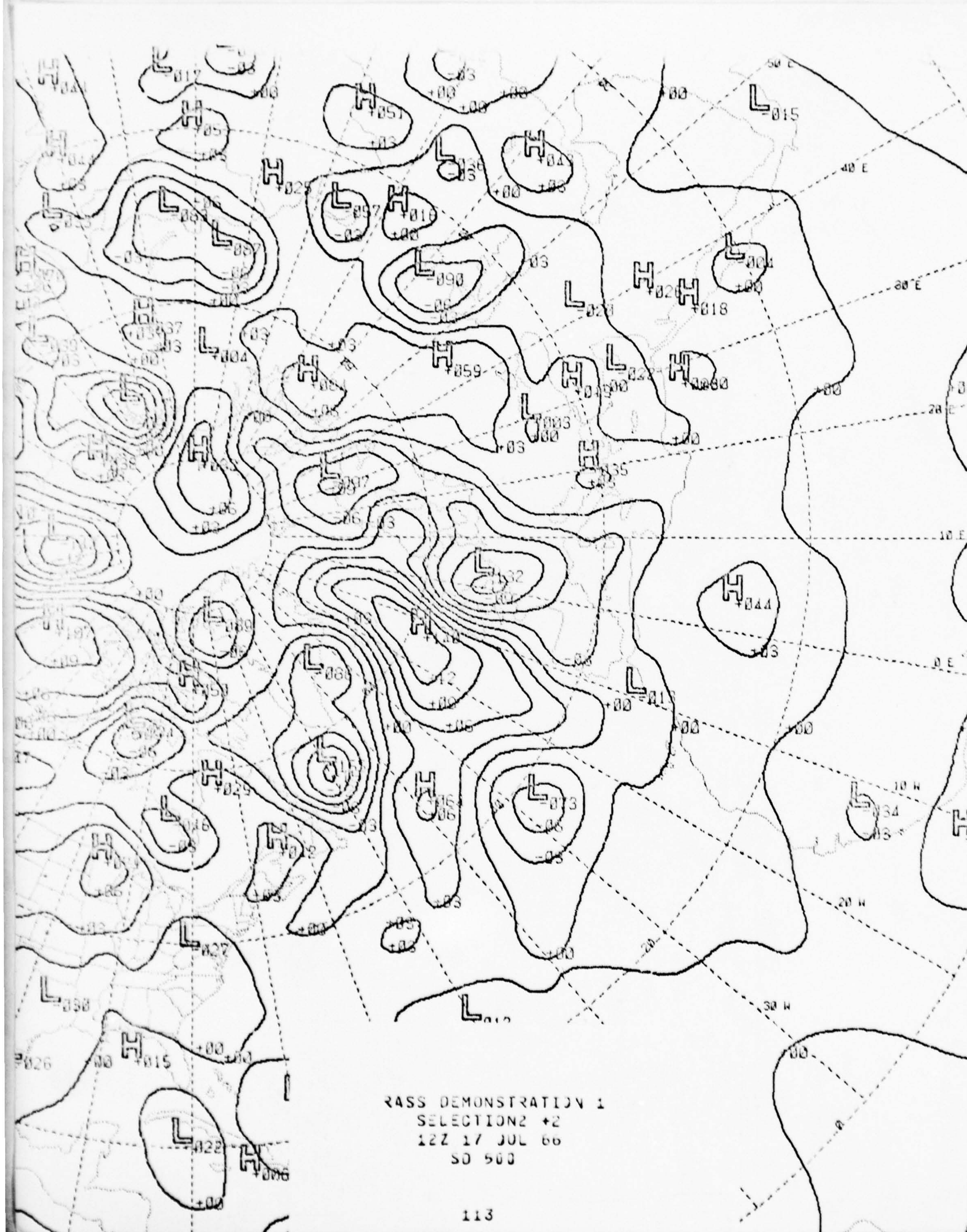

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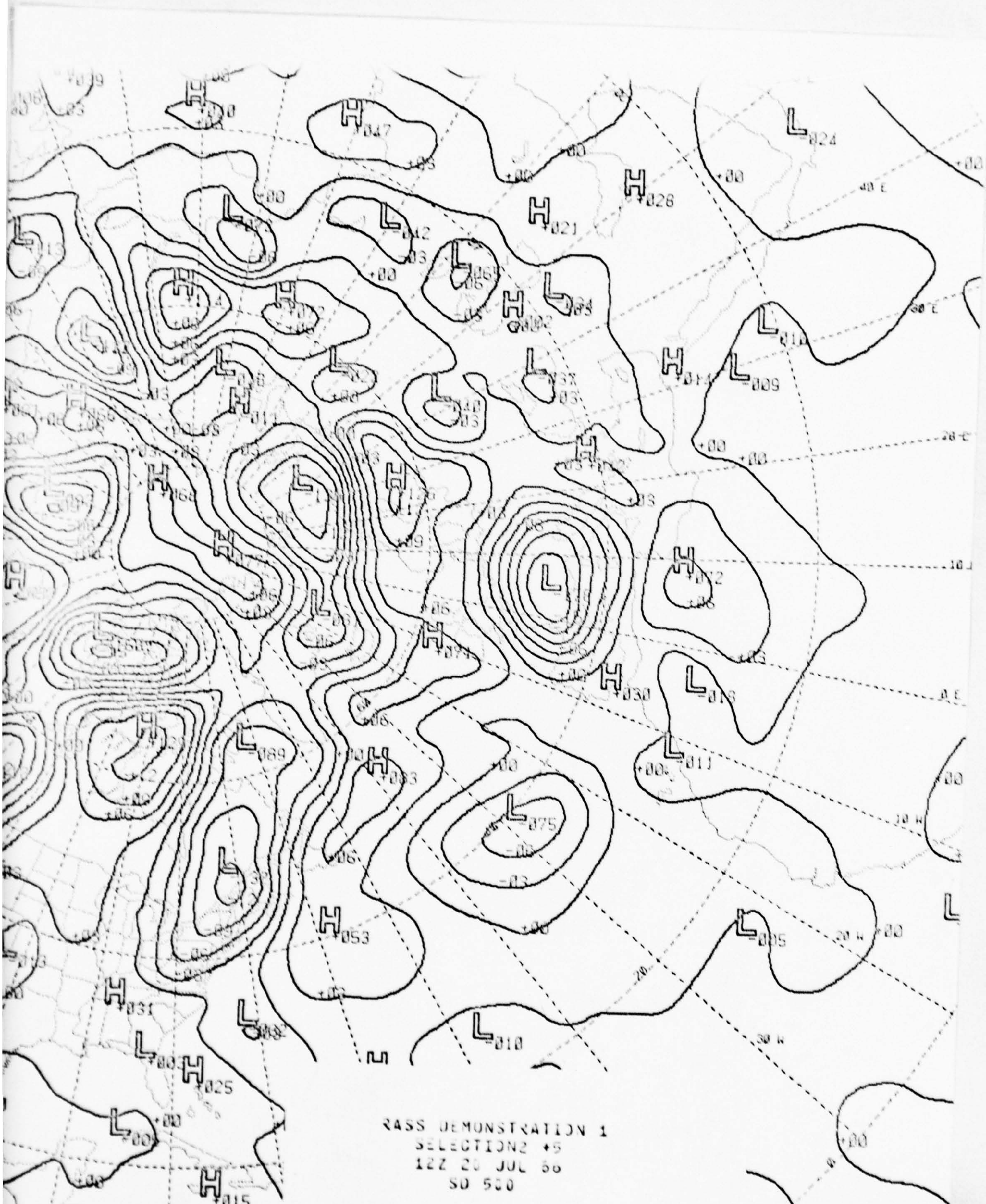
SELECTION2 +2
12Z 17 JUL 66
SD 500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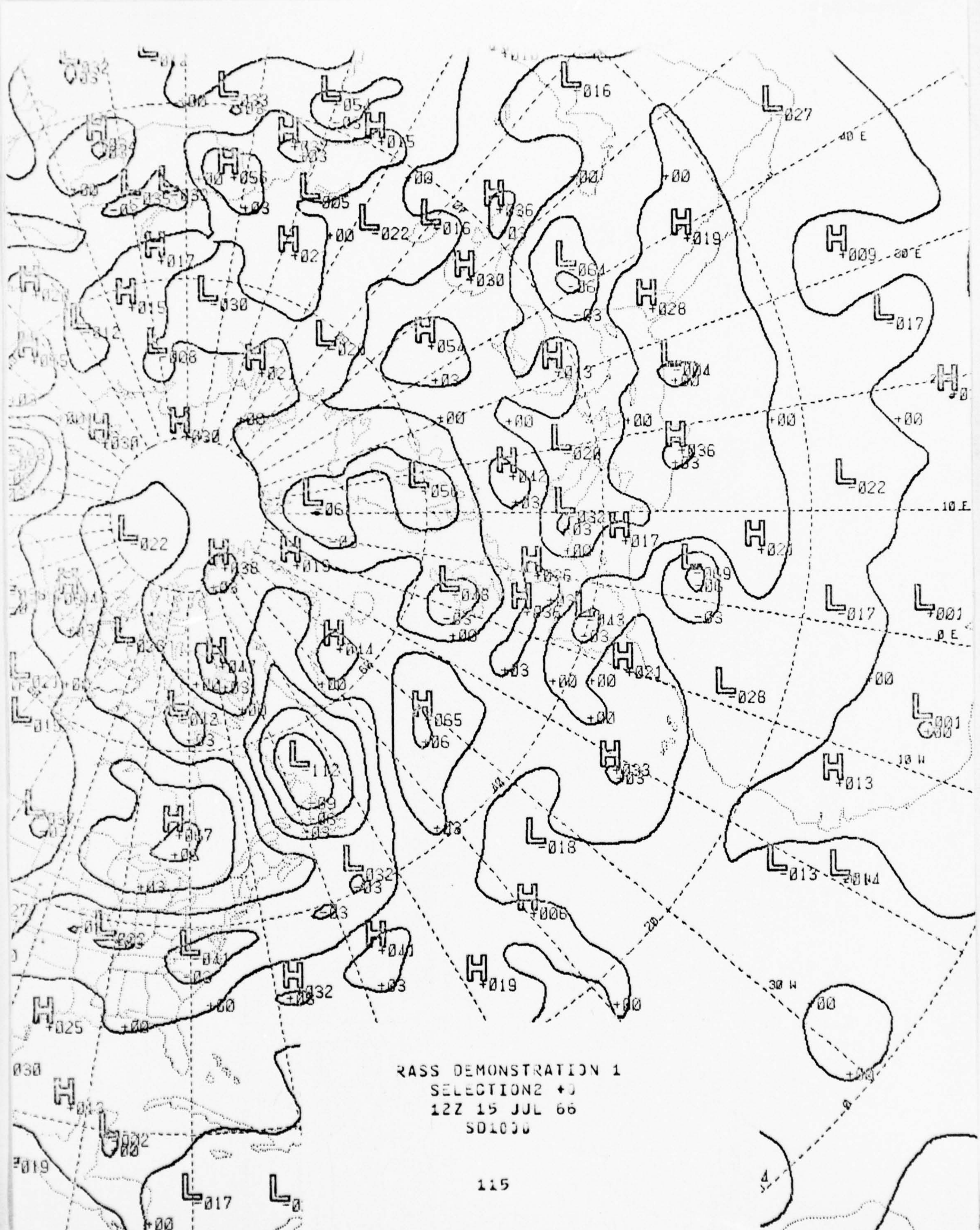
12Z 20 JUL 66
SD 500



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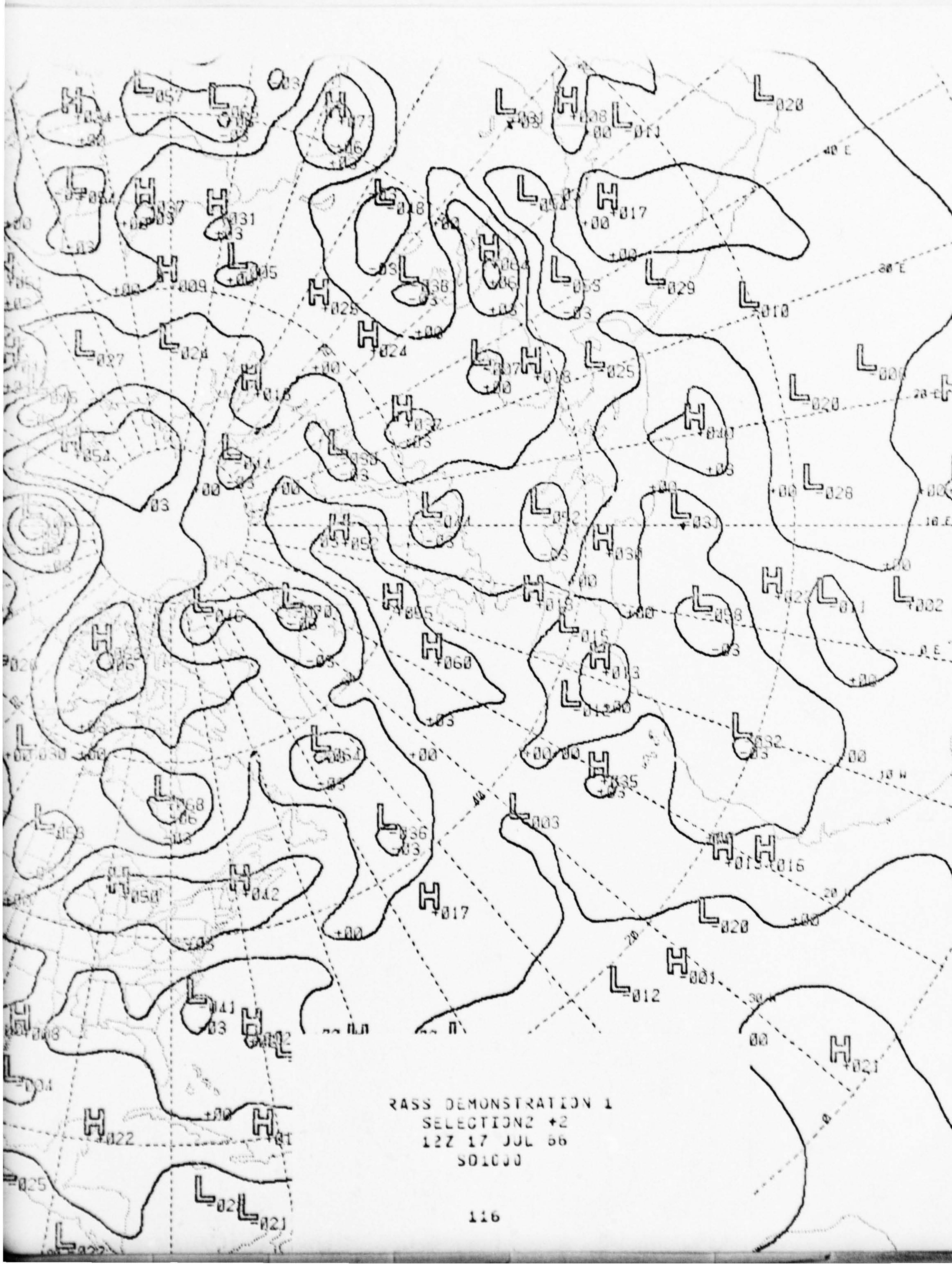
12Z 15 JUL 66
SD1000



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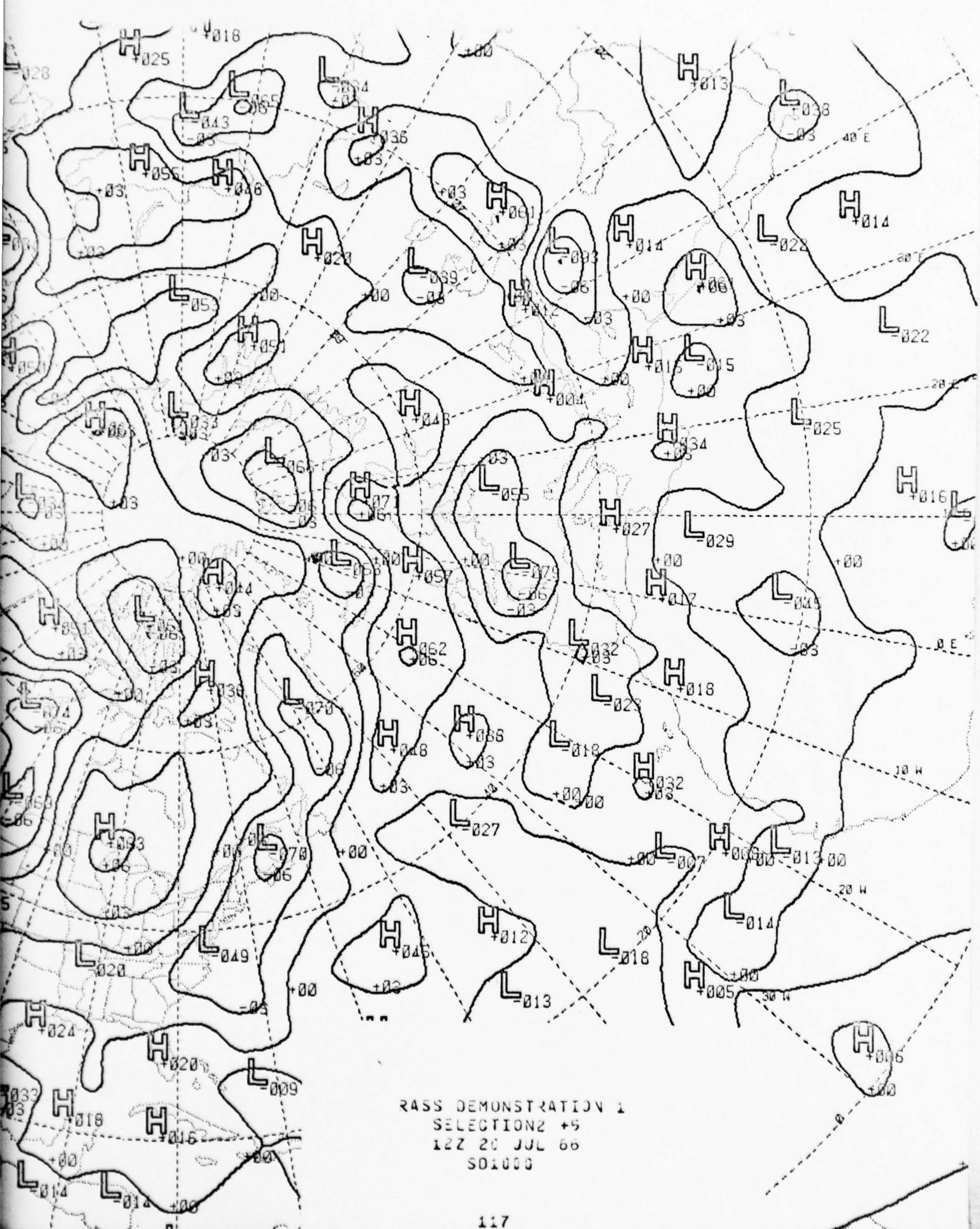
SD1000



RASS DEMONSTRATION 1
SELECTION2 +5
12Z 20 JUL 66
SD1000

8.4.2 RASS Demonstration 2: Baseday 12Z 18 OCT 75

List of contents:

(To facilitate study of the charts, each scenario has been separated from the next by an unnumbered yellow insert; within each scenario sets of component fields are separated by an unnumbered blue insert.)

ANALOGUE SELECTIONS FOR 12Z 18 OCT 75 MEDITERRANEAN REGION

ANALOGUE DTG	SV 500	SV 1000	SV 5-10	SL 500	SL 1000	SL 5-10	SD 500	SD 1000	SD 5-10	TOTAL	FINAL
1. 12Z 18 OCT 75	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
2. 00Z 19 OCT 75	921	975	958	924	936	921	847	876	828	885	
	925	970	962	933	920	922	833	864	821	874	917
3. 00Z 18 OCT 75	933	992	963	942	891	918	805	845	801	864	
	925	977	962	939	921	928	827	843	816	868	912
4. 12Z 17 OCT 75	963	979	979	888	818	867	755	774	767	821	
	943	958	957	898	856	884	772	776	774	821	872
5. 12Z 19 OCT 75	913	942	958	879	876	867	776	806	745	825	
	922	942	947	886	852	878	782	791	766	821	870
6. 00Z 17 OCT 75	937	958	971	858	752	836	706	710	720	775	
	905	945	960	861	787	849	728	731	735	781	830
7. 00Z 20 OCT 75	850	908	942	842	818	836	748	784	704	791	
	870	918	935	839	795	840	743	762	711	780	827
8. 12Z 16 OCT 75	917	942	967	827	736	812	664	667	681	743	
	905	925	942	831	745	820	689	704	694	748	802
9. 12Z 20 OCT 75	846	888	937	797	755	800	744	780	713	778	
	852	905	933	801	743	810	720	754	704	761	796
10. 00Z 11 NOV 68	771	867	779	812	745	830	697	713	667	734	
	775	868	787	783	761	820	703	727	673	736	774
11. 12Z 26 APR 52	792	775	804	773	773	800	659	714	660	720	
	822	782	768	805	759	812	690	746	681	727	774
12. 12Z 10 NOV 68	800	867	796	779	761	797	680	712	663	729	
	790	880	805	779	772	808	686	705	670	723	773
13. 12Z 25 APR 52	833	800	783	812	745	797	660	698	652	718	
	837	803	767	818	740	808	696	697	670	726	770
14. 12Z 27 OCT 64	812	913	812	794	703	842	733	718	723	757	
	793	895	805	806	731	822	733	723	711	751	769
15. 00Z 25 OCT 55	879	921	900	779	688	852	719	681	666	742	
	887	903	857	773	694	830	700	667	661	722	769
16. 00Z 16 OCT 75	858	921	971	791	658	758	653	643	651	713	
	872	922	948	803	706	796	663	676	667	722	769
17. 00Z 21 OCT 75	817	867	913	752	691	797	728	754	704	755	
	827	883	910	767	697	798	707	732	693	741	766
18. 12Z 18 OCT 52	812	879	850	800	779	755	666	684	660	723	
	795	908	825	776	771	746	659	680	667	712	766
19. 12Z 25 OCT 55	883	863	875	773	679	876	696	685	681	738	
	883	873	867	767	693	817	696	680	673	724	766
20. 00Z 22 OCT 55	913	867	850	785	697	809	699	702	679	740	
	885	857	822	787	694	808	704	702	690	733	765
21. 12Z 09 NOV 68	754	888	796	785	770	812	642	677	653	713	
	775	870	805	773	761	791	675	689	665	717	765
22. 12Z 24 OCT 75	858	925	888	709	733	758	673	703	678	730	
	852	908	897	715	736	752	678	706	675	722	765
23. 12Z 11 NOV 68	767	833	792	761	748	821	647	713	664	718	
	780	847	797	775	749	809	678	723	682	728	764
24. 12Z 15 NOV 49	767	833	833	806	718	830	722	744	652	741	
	780	838	828	778	725	801	736	741	670	741	764
25. 12Z 03 NOV 58	871	925	854	773	697	836	708	673	680	738	
	850	917	852	769	702	805	696	683	673	725	764

8-DAY VERIFICATION SUMMARY

BASEDAY : 127 18 OCT 75
ANALOGUE: CLIMATOLOGY
RANK : 0
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	867	854	879	883	875	871	867	871	867
	1000:	842	842	821	783	792	829	875	883	913
	5-10:	850	825	871	871	858	842	846	850	863
SL	500:	717	650	625	650	683	667	675	750	808
	1000:	633	642	608	642	625	658	725	783	717
	5-10:	783	725	742	753	825	775	775	792	783
SD	500:	694	647	647	639	656	625	647	656	647
	1000:	625	625	661	653	703	708	697	694	697
	5-10:	664	675	636	633	611	633	647	678	717
FINAL		762	737	740	756	756	759	765	796	795

BASEDAY : 127 18 OCT 75
ANALOGUE: PERSISTENCE
RANK : 0
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	1000	913	846	800	825	829	858	863	850
	1000:	1000	942	888	875	858	896	925	933	904
	5-10:	1000	958	937	904	892	883	888	883	879
SL	500:	1000	867	808	750	733	733	742	733	708
	1000:	1000	875	758	658	675	708	725	650	633
	5-10:	1000	858	808	617	808	808	792	775	733
SD	500:	1000	781	769	706	683	653	625	633	592
	1000:	1000	789	781	728	722	622	611	642	617
	5-10:	1000	767	711	719	714	642	656	675	642
FINAL		1000	879	815	769	789	787	791	766	747

BASEDAY : 127 18 OCT 75
ANALOGUE: 002 11 NOV 68
RANK : 1
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	771	754	754	767	721	729	717	754	825
	1000:	867	875	871	892	846	863	863	879	858
	5-10:	779	808	788	783	804	825	796	804	821
SL	500:	900	833	875	842	808	792	783	758	708
	1000:	775	758	750	850	833	758	717	700	650
	5-10:	842	817	800	775	842	792	808	800	792
SD	500:	631	636	636	679	700	597	514	550	550
	1000:	550	694	706	675	703	614	528	663	611
	5-10:	542	644	633	642	644	569	517	572	565
FINAL		813	795	774	793	810	757	753	766	756

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 26 APR 52
RANK : 2
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	792	671	867	754	717	729	771	704	671
	1000:	775	733	721	679	687	750	733	696	700
	5-10:	804	779	775	758	779	742	771	763	754
SL	500:	808	825	750	800	783	750	642	608	625
	1000:	825	825	758	775	733	717	633	592	608
	5-10:	850	833	825	825	817	800	750	717	692
SD	500:	603	672	669	628	594	603	553	633	575
	1000:	642	675	692	703	689	667	597	597	639
	5-10:	594	714	667	636	564	608	528	589	625
FINAL		794	813	791	787	762	761	727	689	688

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 10 NOV 68
RANK : 3
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	800	754	771	746	725	721	733	750	825
	1000:	867	883	892	875	838	838	863	879	833
	5-10:	796	800	779	763	808	817	800	804	812
SL	500:	833	875	875	833	800	808	758	750	683
	1000:	775	792	717	858	825	742	717	683	650
	5-10:	850	850	833	783	825	783	767	750	758
SD	500:	594	647	619	600	631	644	514	519	594
	1000:	675	703	678	622	667	689	556	561	600
	5-10:	639	667	653	619	631	625	525	589	594
FINAL		816	817	775	779	769	764	743	759	754

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 25 APR 52
RANK : 4
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	833	846	896	779	738	696	742	767	692
	1000:	800	742	713	708	679	717	746	708	692
	5-10:	783	738	758	750	738	763	754	783	758
SL	500:	842	825	817	758	833	763	675	633	633
	1000:	775	850	708	758	775	733	667	642	608
	5-10:	833	842	833	850	817	817	733	783	692
SD	500:	564	639	656	689	611	614	608	600	664
	1000:	644	686	678	706	775	694	617	650	667
	5-10:	572	617	675	669	597	597	578	508	644
FINAL		795	816	765	773	775	767	729	718	704

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 27 OCT 64
RANK : 5
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	812	812	842	867	871	888	883	900	858
	1000:	913	900	817	758	842	800	900	908	846
	5-10:	812	808	854	858	846	850	871	867	888
SL	500:	758	733	700	717	717	692	808	758	700
	1000:	675	708	633	625	600	633	733	708	658
	5-10:	675	800	850	858	817	808	783	783	717
SD	500:	681	622	650	667	669	614	578	558	614
	1000:	681	644	656	622	647	611	628	678	728
	5-10:	667	706	631	581	614	578	569	606	625
FINAL		753	767	763	750	730	726	763	763	748

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 00Z 25 OCT 55
RANK : 6
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	879	875	804	750	683	717	671	663	679
	1000:	921	875	846	804	808	792	821	775	779
	5-10:	900	892	913	821	838	796	767	783	825
SL	500:	817	692	608	667	667	608	625	542	675
	1000:	658	608	600	625	592	517	592	700	650
	5-10:	892	783	692	733	742	692	658	625	675
SD	500:	717	683	575	619	608	553	575	625	714
	1000:	658	578	567	625	667	639	592	711	694
	5-10:	672	653	678	636	586	572	578	617	650
FINAL		777	713	705	731	705	644	669	700	731

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 18 OCT 52
RANK : 7
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	812	779	896	888	850	804	800	783	821
	1000:	879	925	950	904	821	746	779	821	825
	5-10:	850	821	863	850	863	817	838	850	846
SL	500:	833	825	783	717	750	725	650	683	700
	1000:	792	858	700	717	733	742	675	663	700
	5-10:	792	825	775	767	825	800	725	717	742
SD	500:	631	592	617	567	550	608	572	492	511
	1000:	642	667	566	644	639	642	608	636	622
	5-10:	642	575	603	533	606	614	603	553	536
FINAL		797	824	771	783	787	787	752	748	766

8-DAY VERIFICATION SUMMARY

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 25 OCT 55
RANK : 8
REGION : MEDITERRANEAN

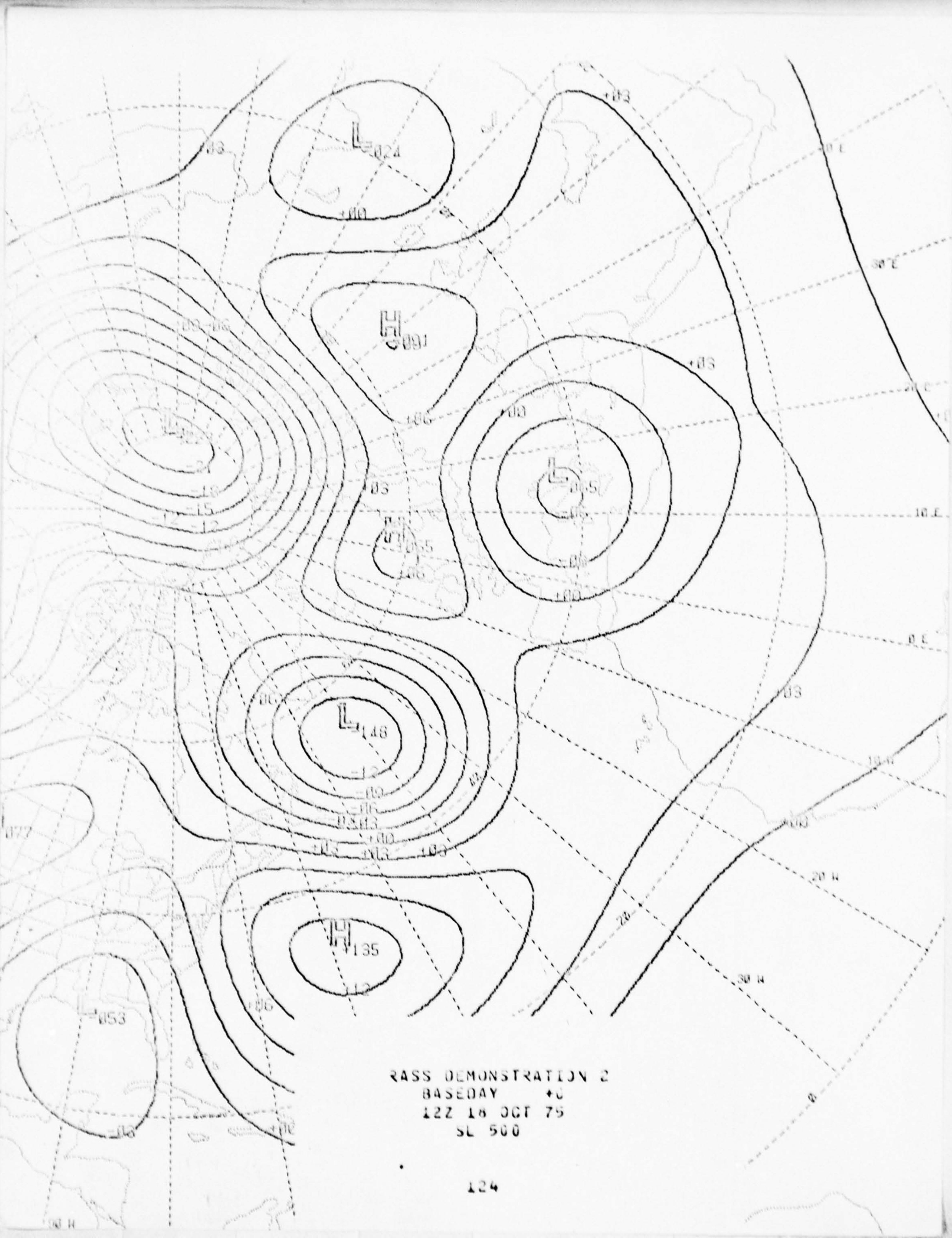
		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	882	904	838	792	725	721	683	671	679
	1000:	863	838	808	821	779	788	796	779	779
	5-10:	875	863	908	888	829	792	800	771	817
SL	500:	908	667	592	700	642	583	575	558	675
	1000:	658	567	608	678	575	550	617	717	675
	5-10:	925	767	675	725	700	658	633	642	700
SD	500:	675	606	525	647	564	533	542	658	686
	1000:	629	533	569	683	614	594	608	700	678
	5-10:	558	653	656	619	583	556	564	619	681
FINAL		769	709	719	732	694	644	666	715	738

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 00Z 22 OCT 55
RANK : 9
REGION : MEDITERRANEAN

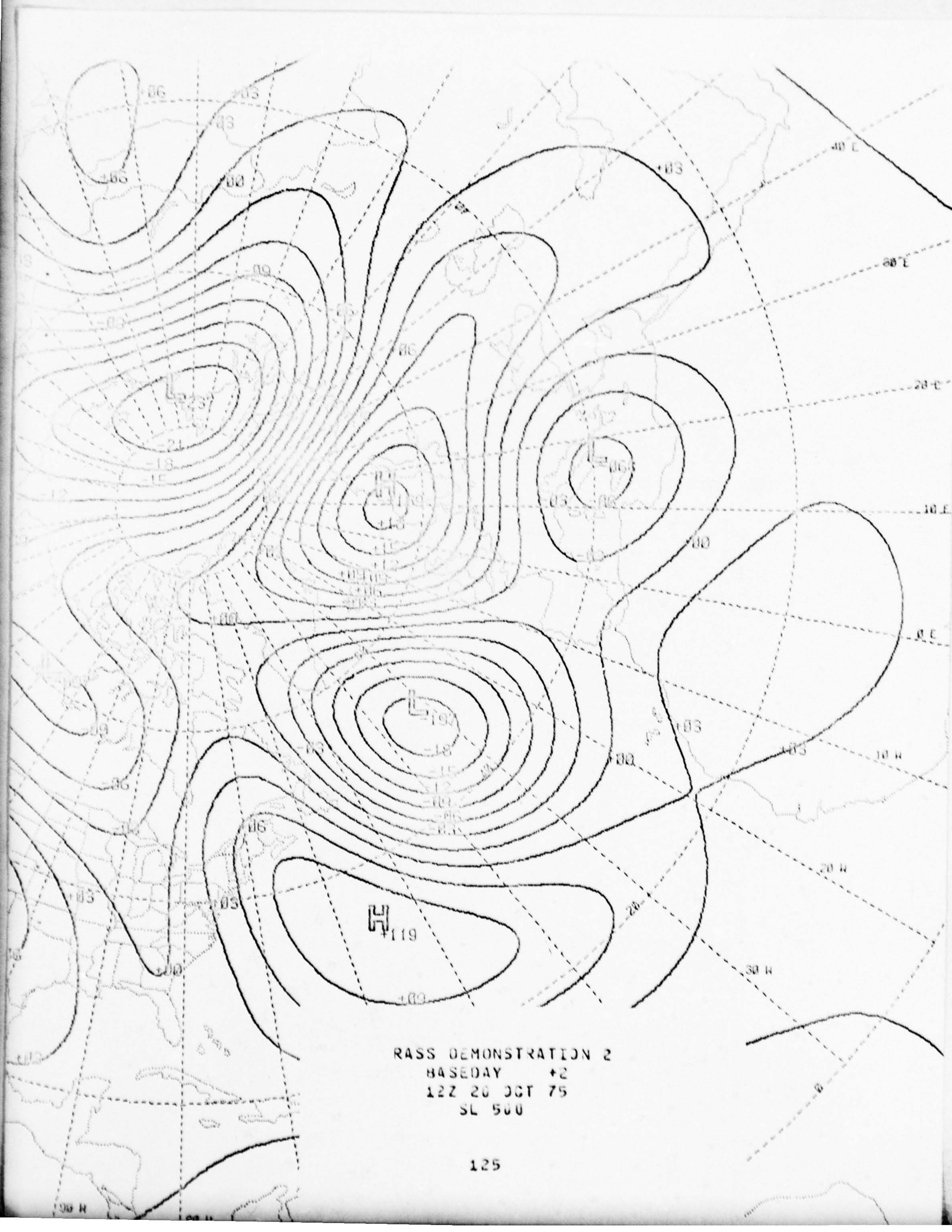
		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	913	875	896	879	796	771	767	713	746
	1000:	867	879	825	821	842	829	829	825	792
	5-10:	850	783	879	913	875	867	804	838	850
SL	500:	792	692	683	667	692	633	608	583	583
	1000:	683	608	675	633	658	500	542	500	625
	5-10:	817	792	708	792	800	708	708	658	617
SD	500:	561	592	572	656	575	619	572	586	581
	1000:	644	647	678	653	678	608	625	708	656
	5-10:	578	606	553	625	583	642	594	642	622
FINAL		761	737	763	757	768	662	695	659	706

BASEDAY : 12Z 18 OCT 75
ANALOGUE: 12Z 09 NOV 68
RANK : 10
REGION : MEDITERRANEAN

		+0	+1	+2	+3	+4	+5	+6	+7	+8
SV	500:	754	779	788	742	721	713	725	754	812
	1000:	888	900	879	879	833	825	825	871	842
	5-10:	796	804	779	779	763	833	812	804	817
SL	500:	858	800	867	817	883	750	783	750	708
	1000:	800	767	775	800	808	808	692	658	633
	5-10:	850	825	817	858	825	792	767	767	742
SD	500:	583	619	658	583	650	639	611	572	556
	1000:	678	703	717	575	689	672	650	625	581
	5-10:	603	639	694	594	614	614	594	578	544
FINAL		817	809	802	777	789	793	751	738	748



RASS DEMONSTRATION 2
BASEDAY +0
12Z 18 OCT 75
SL 500



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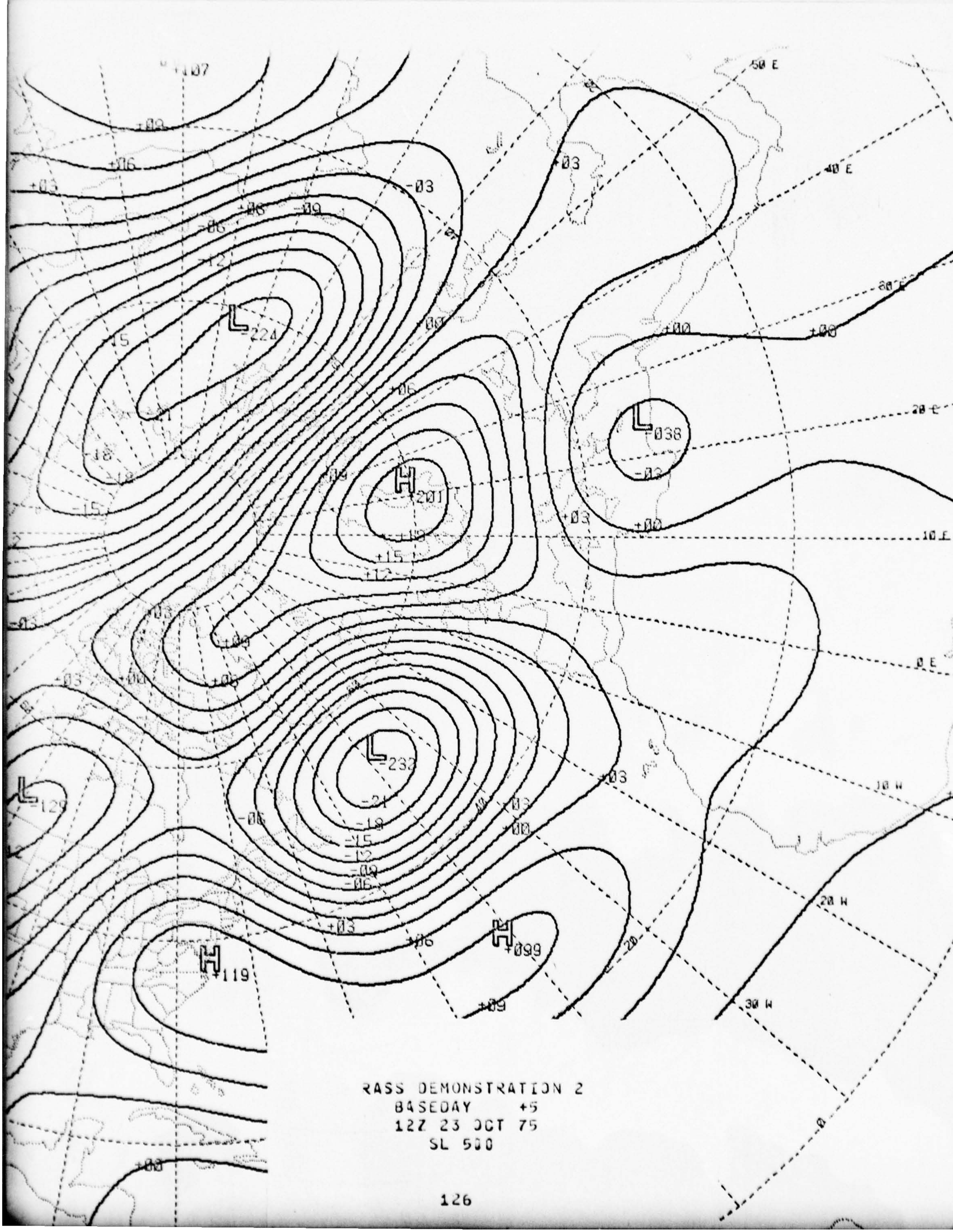
12Z 20 OCT 75
SL 500



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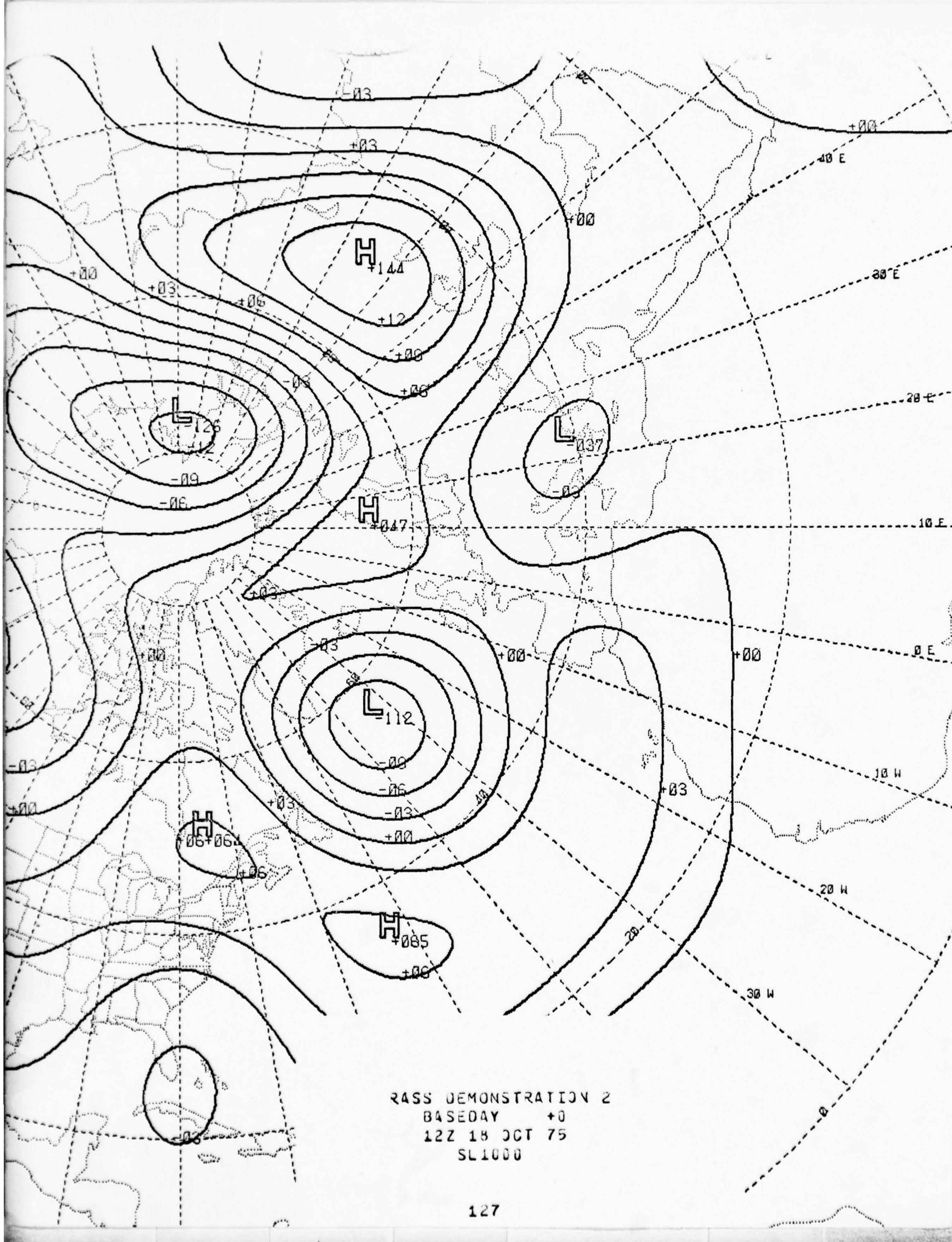
12Z 23 OCT 75
SL 500



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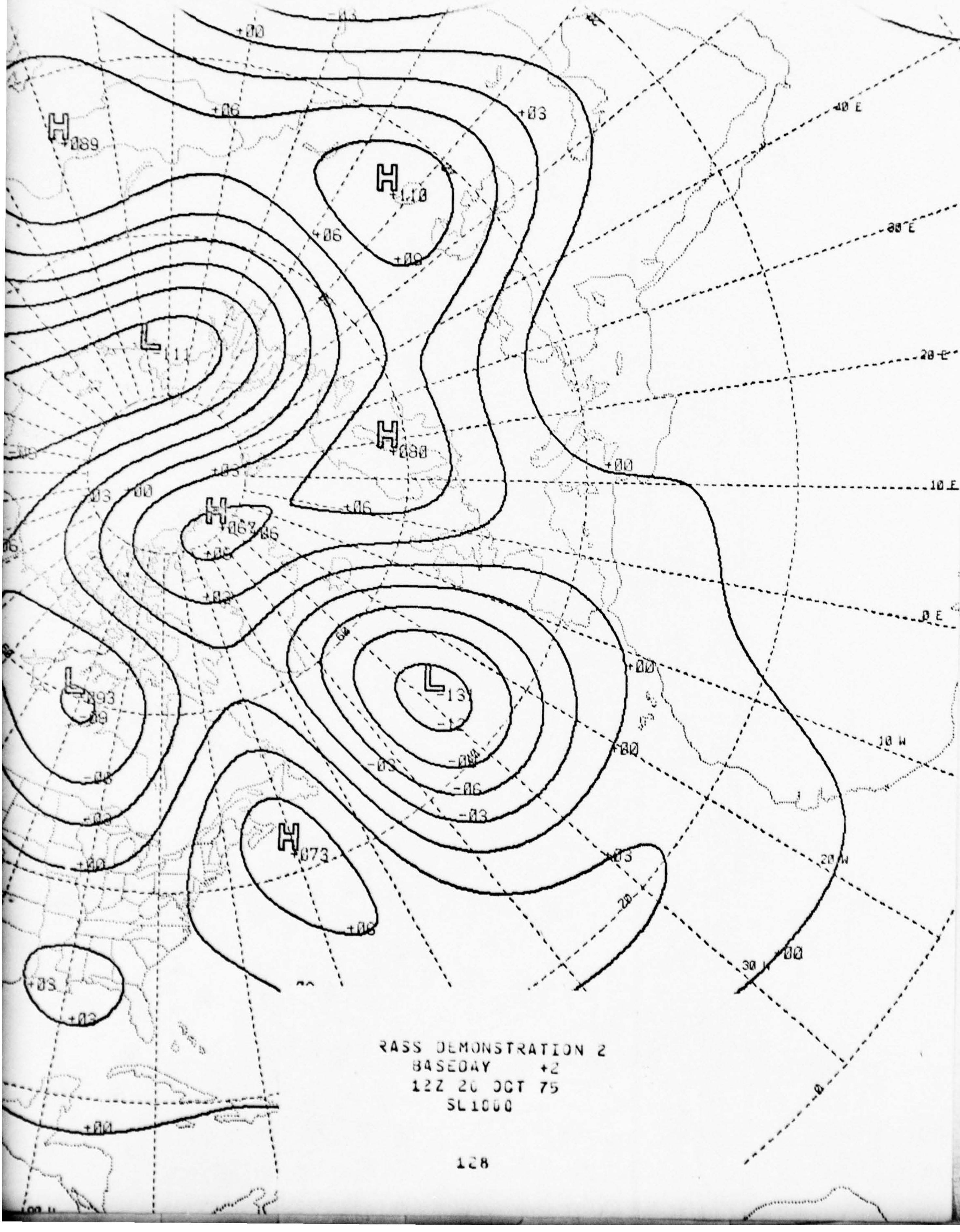
12Z 18 OCT 75
SL1000



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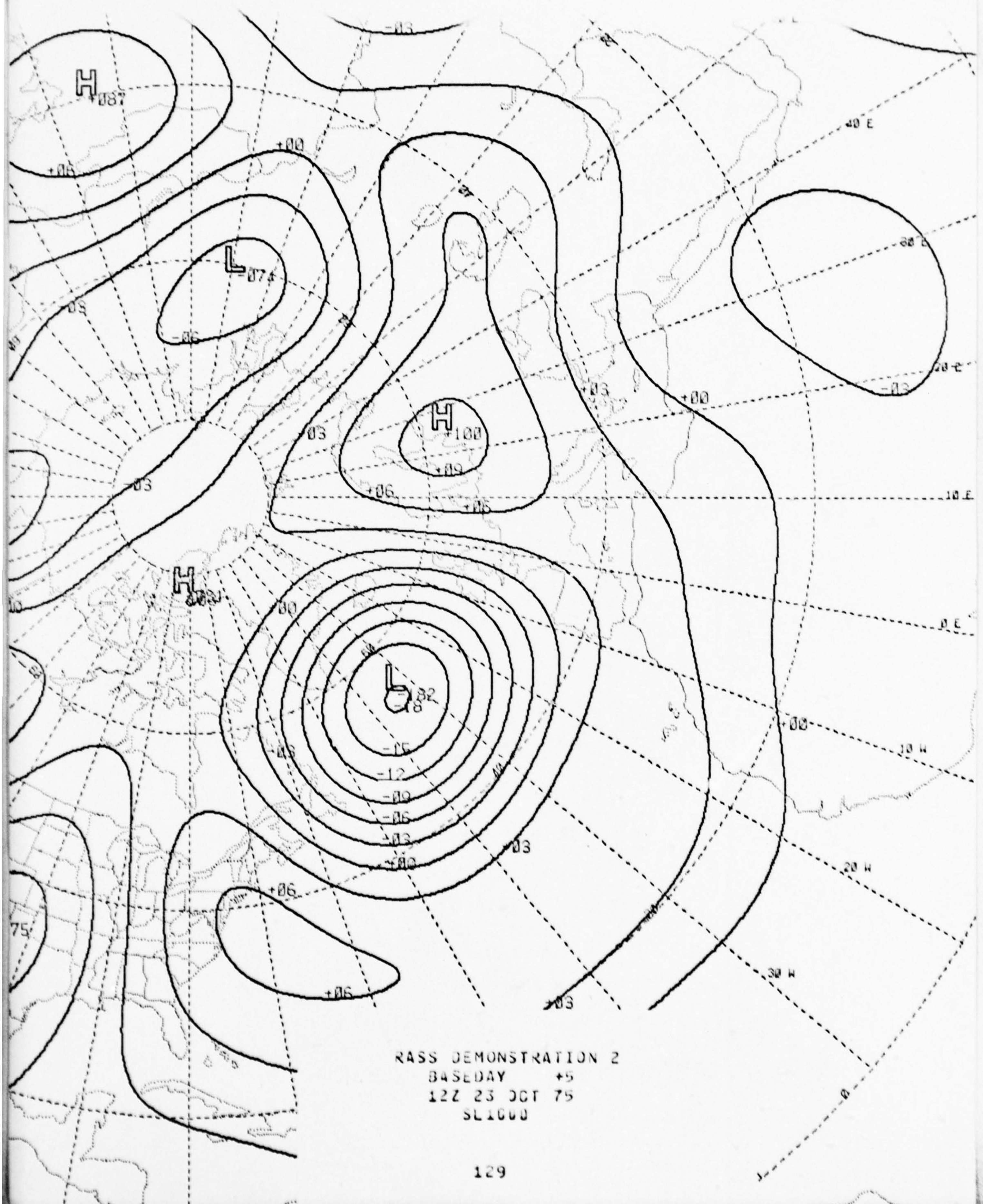
BASEDAY +2
12Z 20 OCT 75
SL1000



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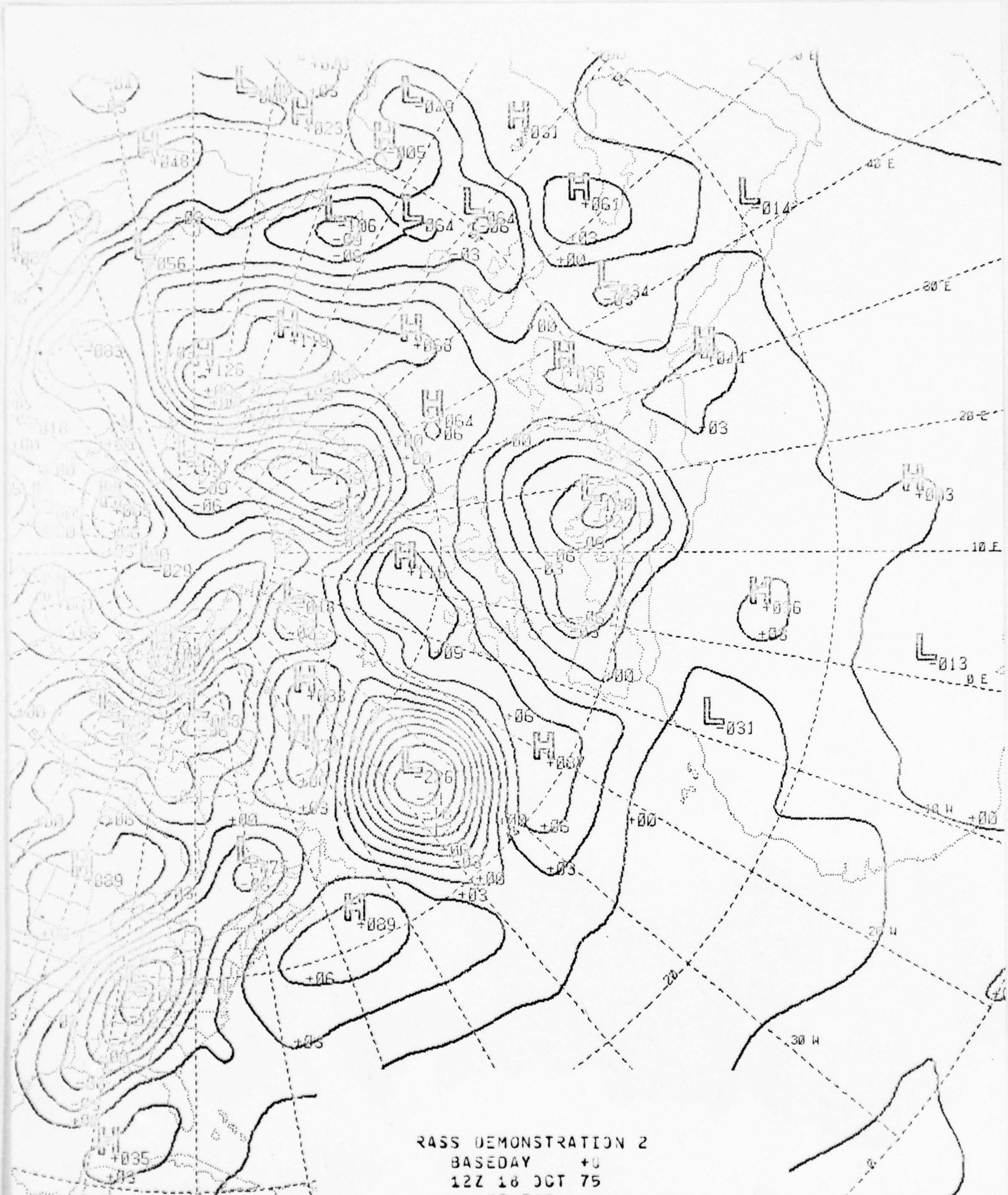
12Z 23 OCT 75
SL1000



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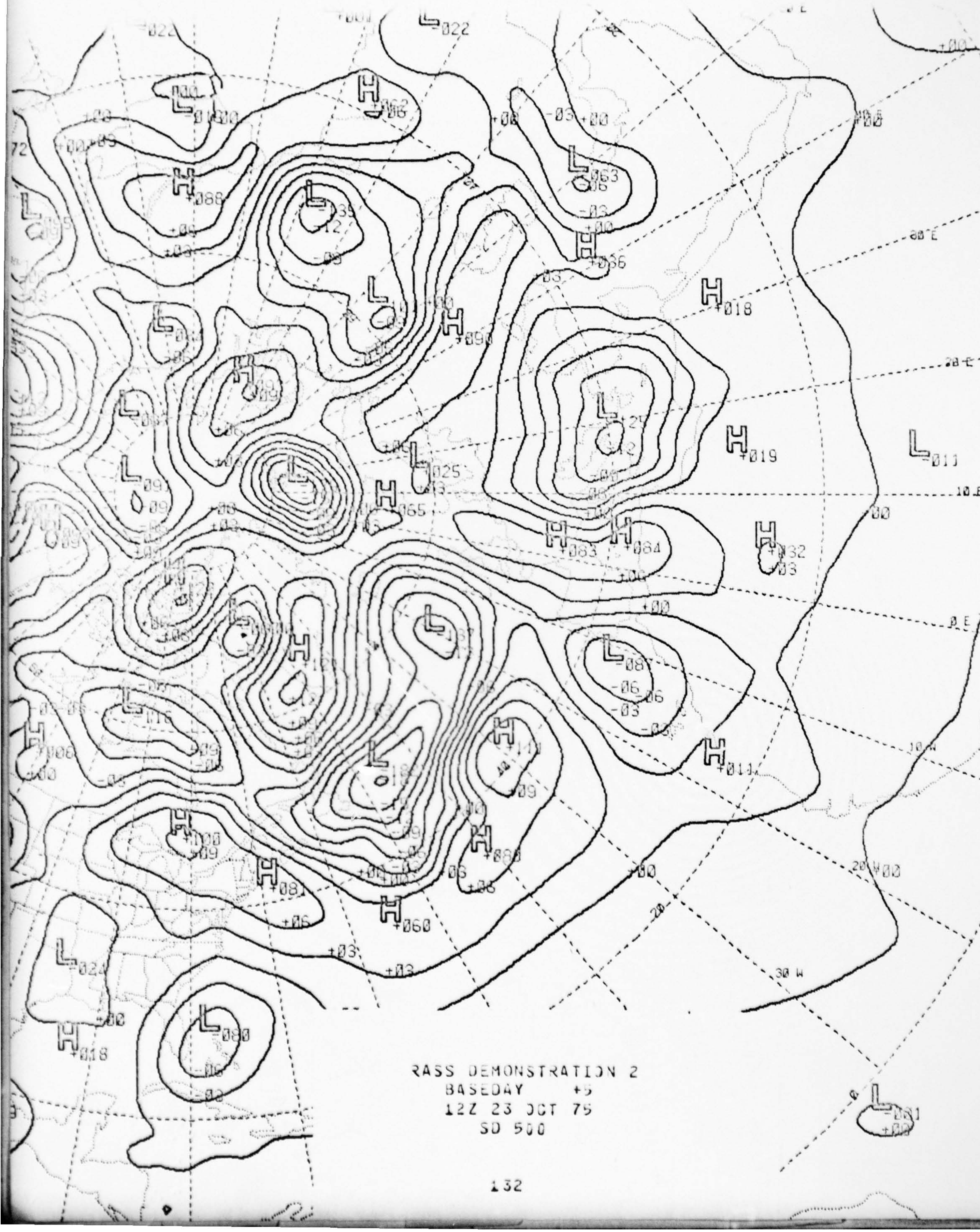
BASEDAY +0
12Z 18 OCT 75
SD 500

RASS DEMONSTRATION 2
BASEDAY +2
12Z 20 OCT 75
SD 500



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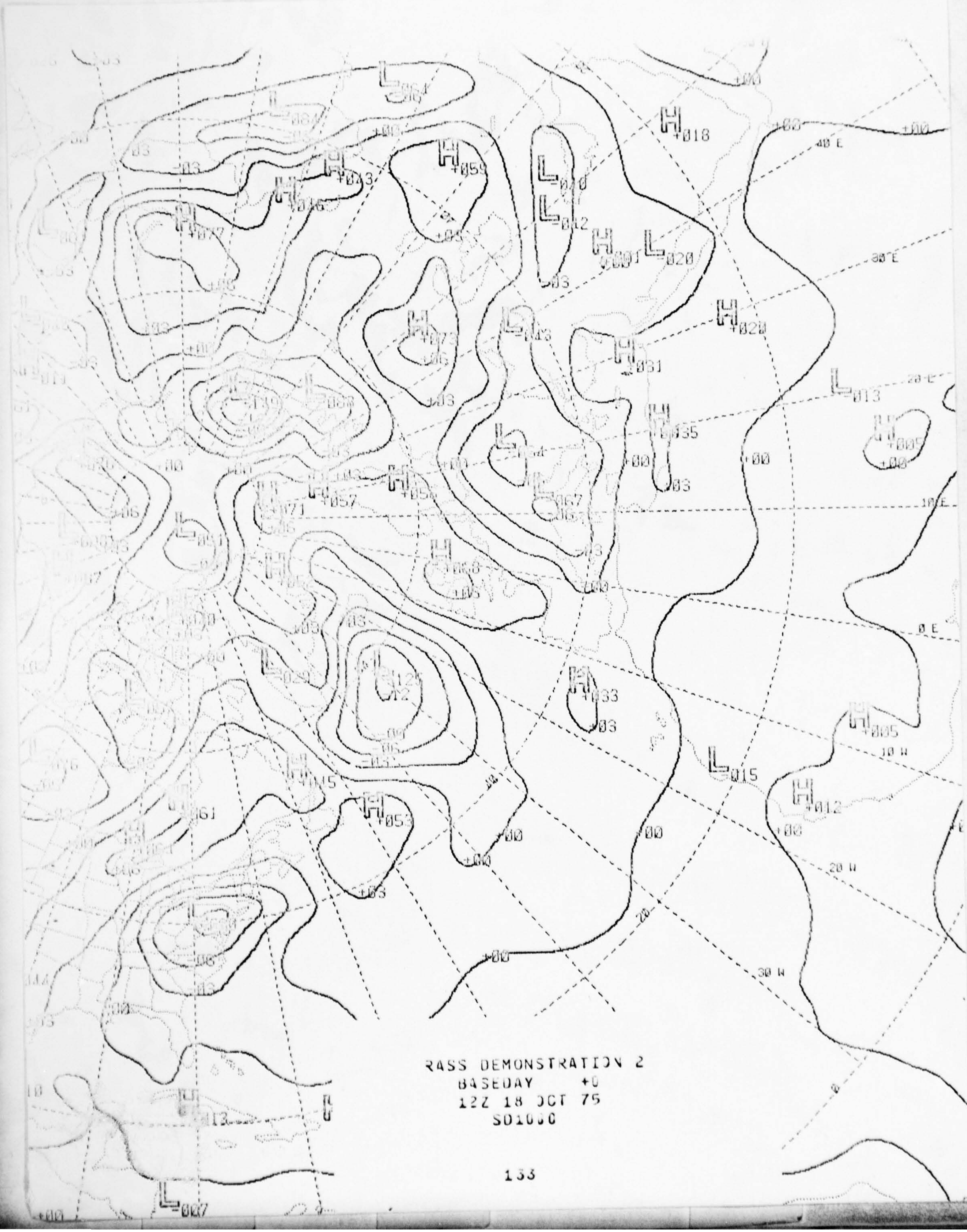
12Z 23 OCT 75
SD 500



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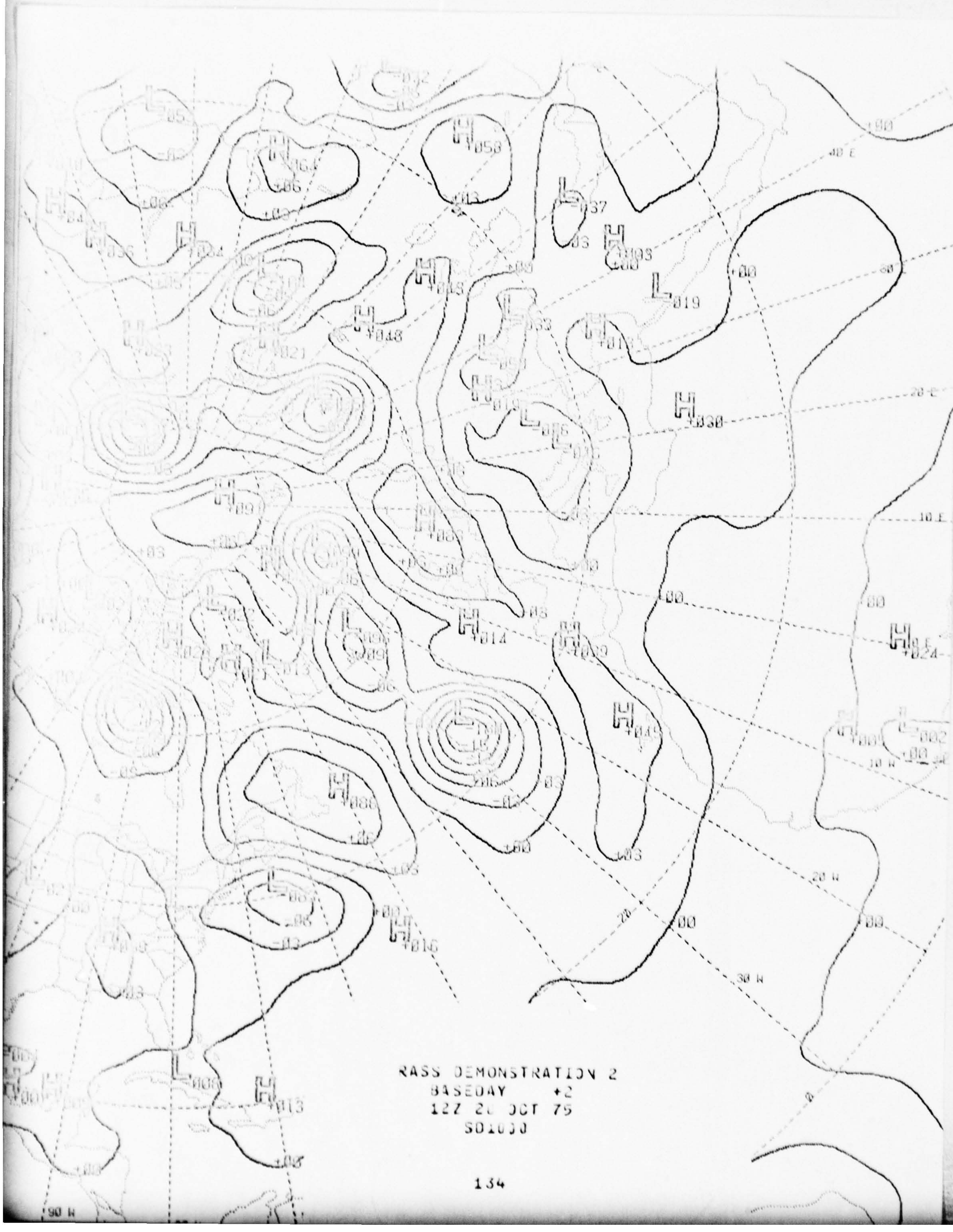
BASEDAY +0
12Z 18 OCT 75
SD1000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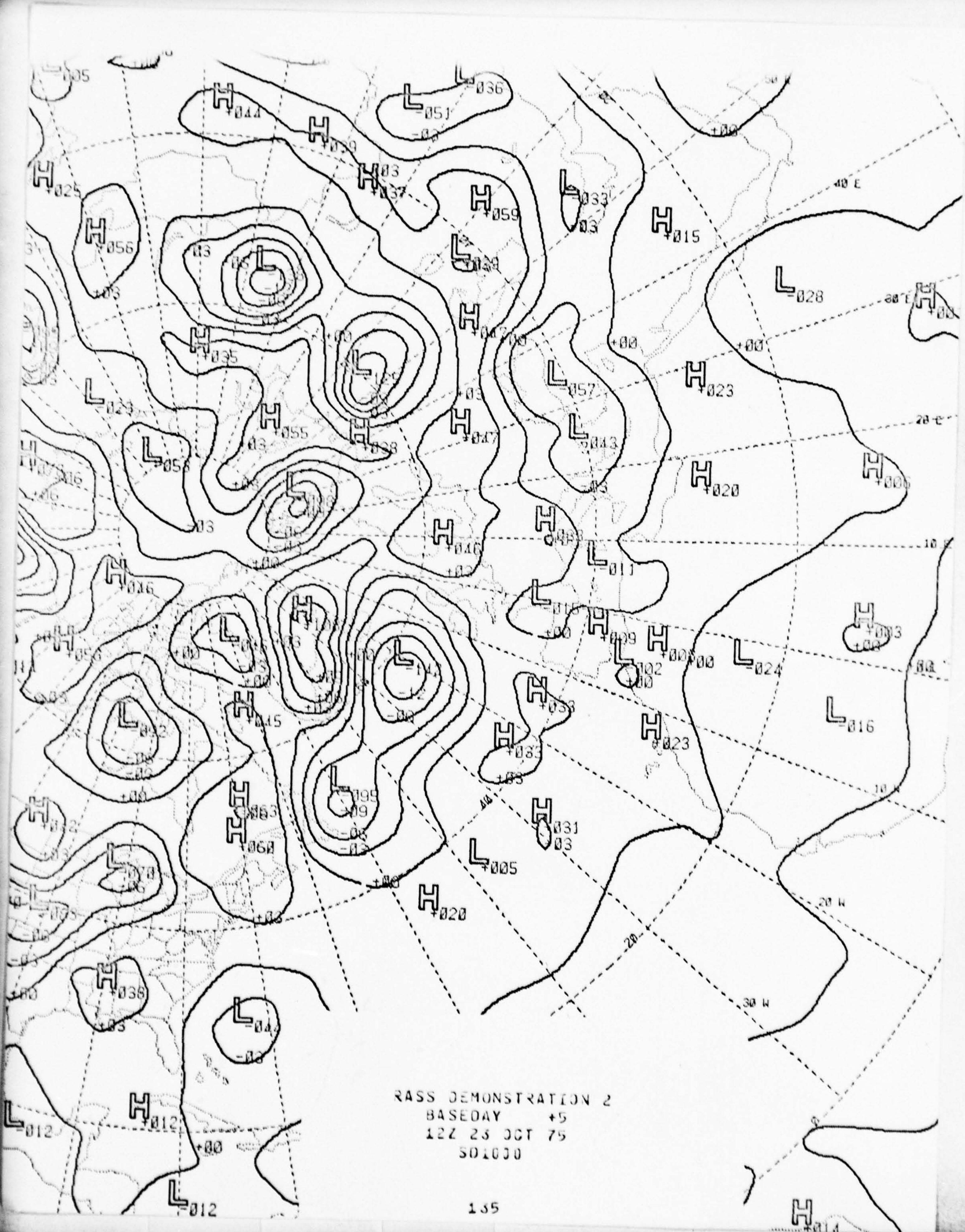
BASEDAY +2
12Z 20 OCT 75
SD1000



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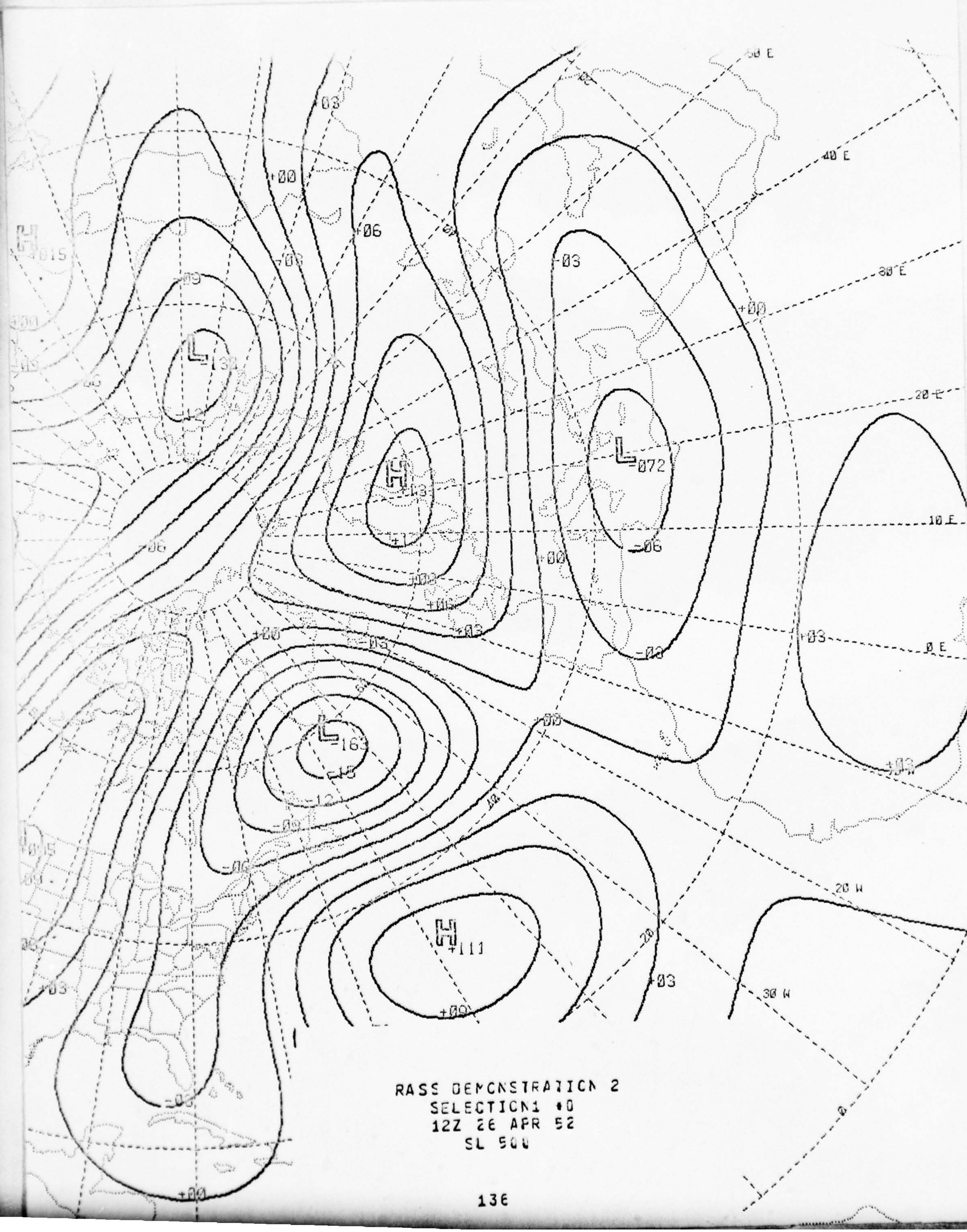
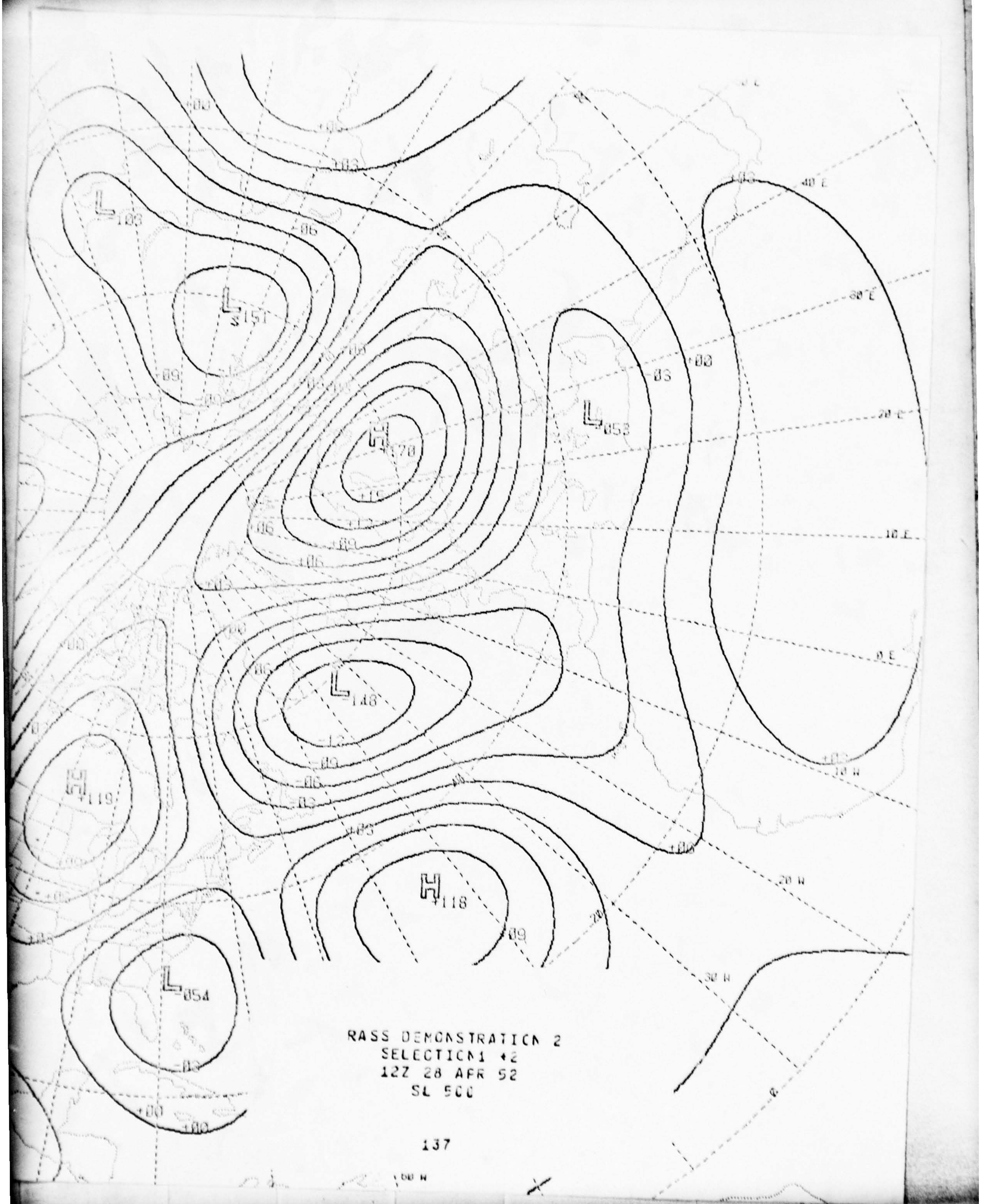
BASEDAY +5
12Z 23 OCT 75
SD1030



RASS DEMONSTRATION 2
SELECTION1 +0
12Z 26 APR 52
SL 500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L 148
H 119
H 118
L 054
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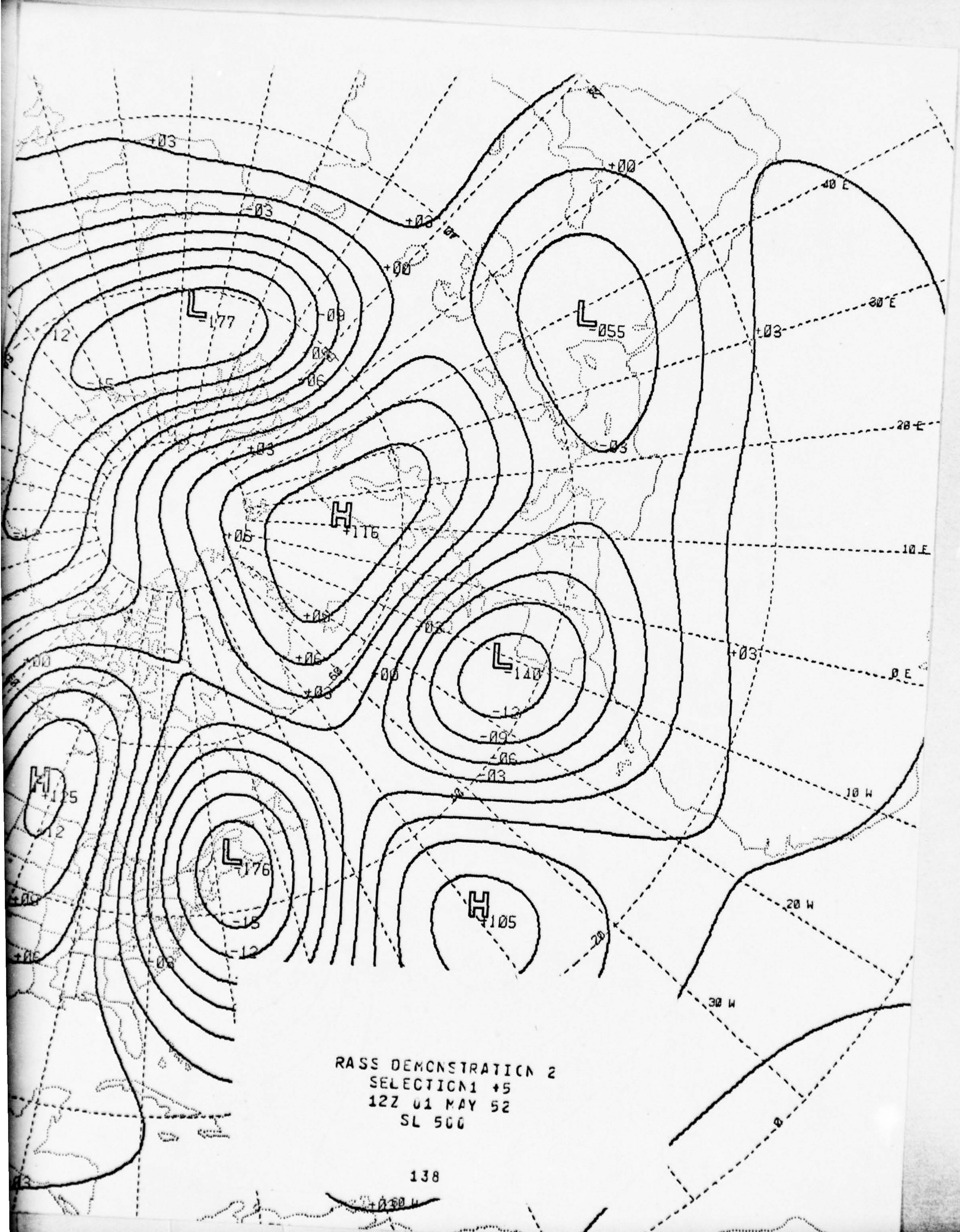
60 W
RASS DEMONSTRATION 2
SELECTION1 +2
12Z 28 APR 52
SL 500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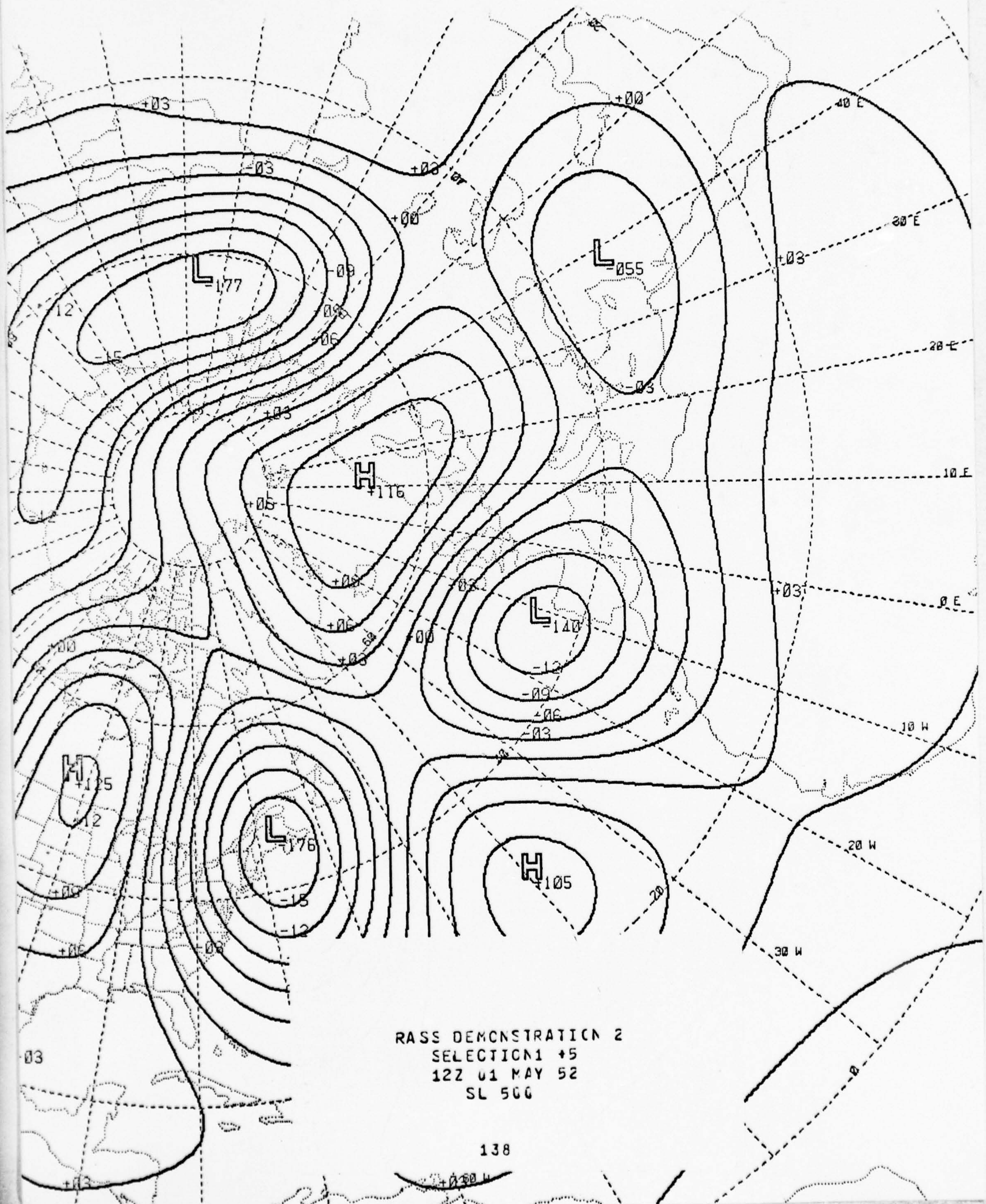
SELECTION1 +5
12Z 01 MAY 52
SL 500



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12Z 01 MAY 52
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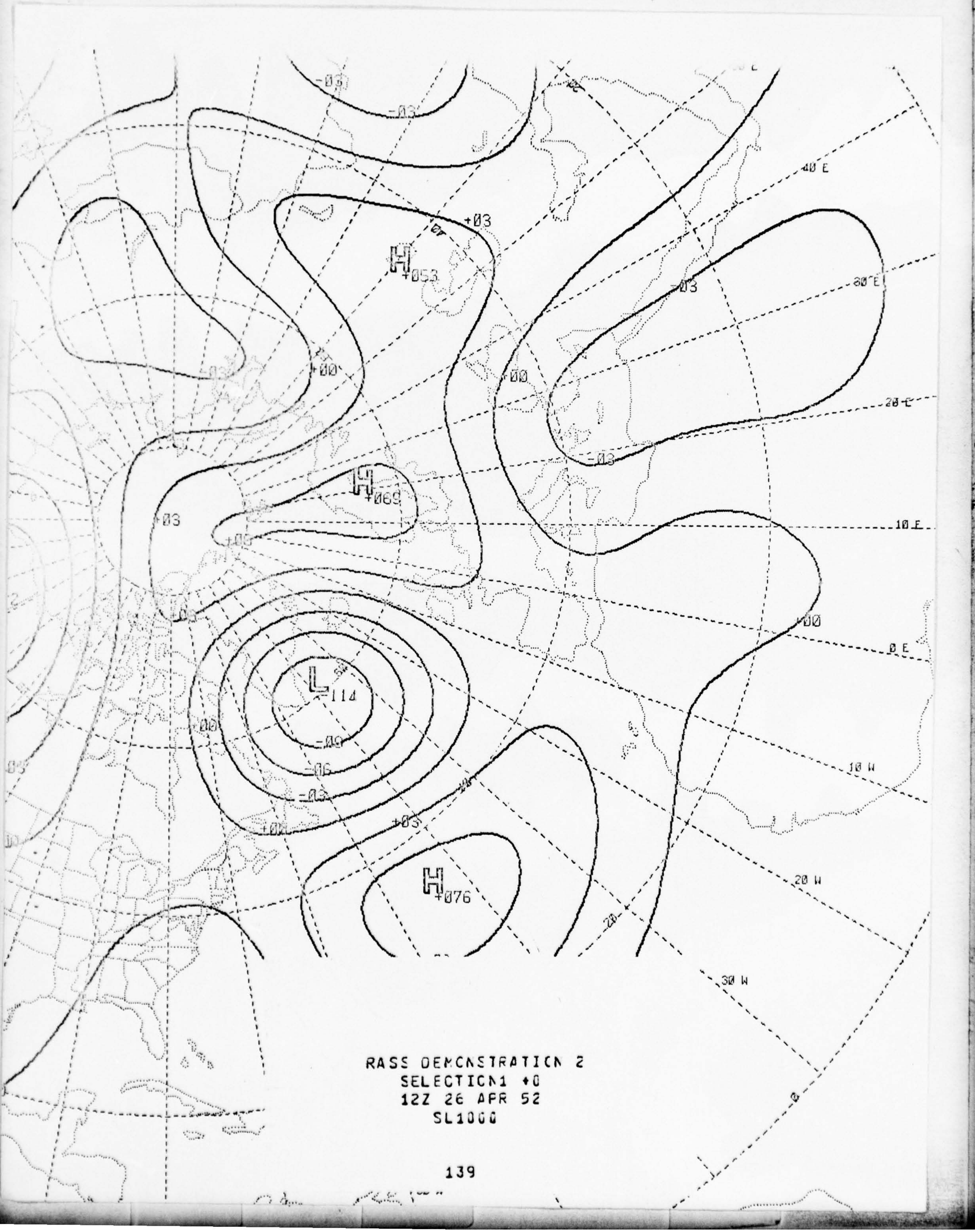

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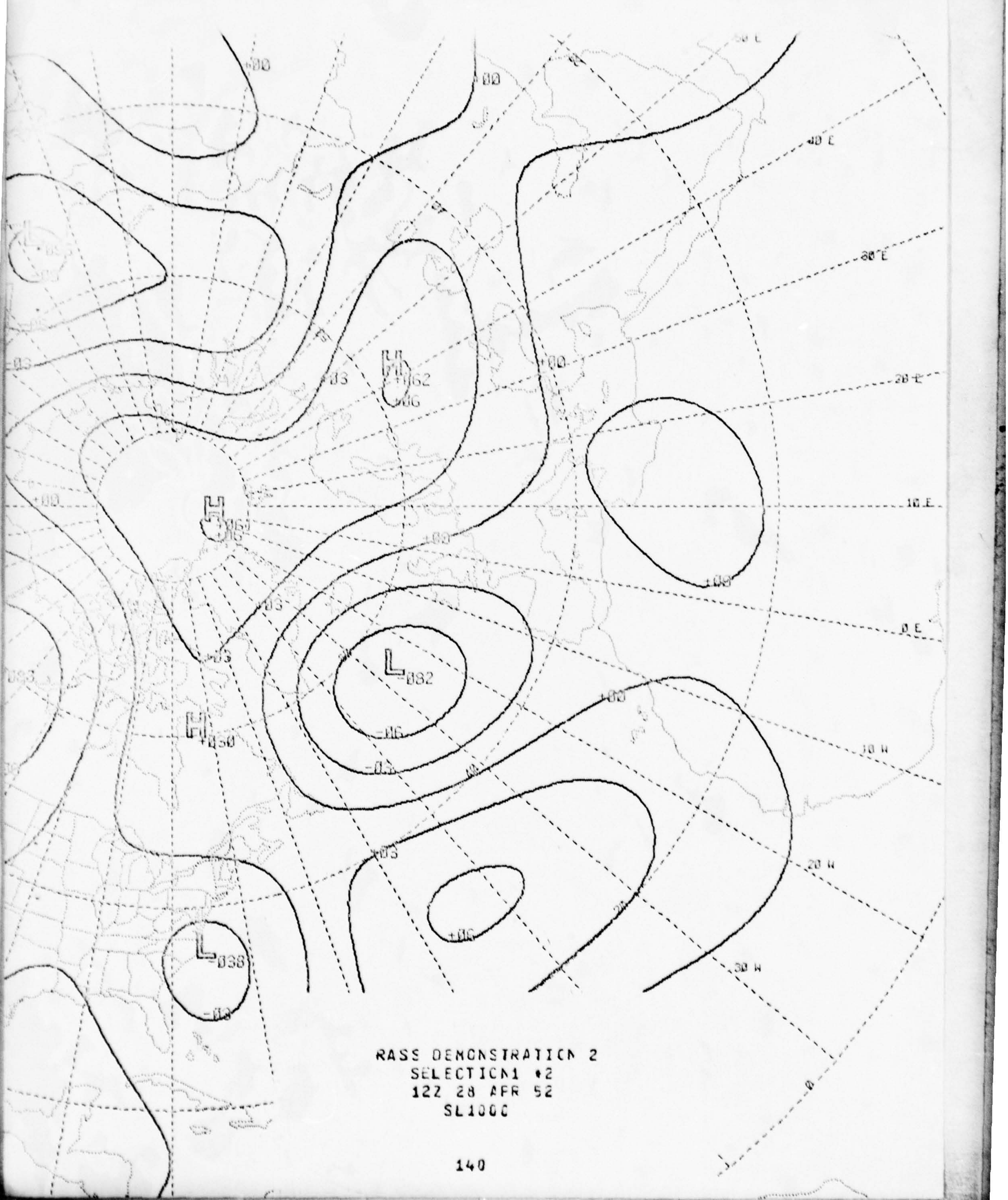
SELECTION1 +0
12Z 26 APR 52
SL1000



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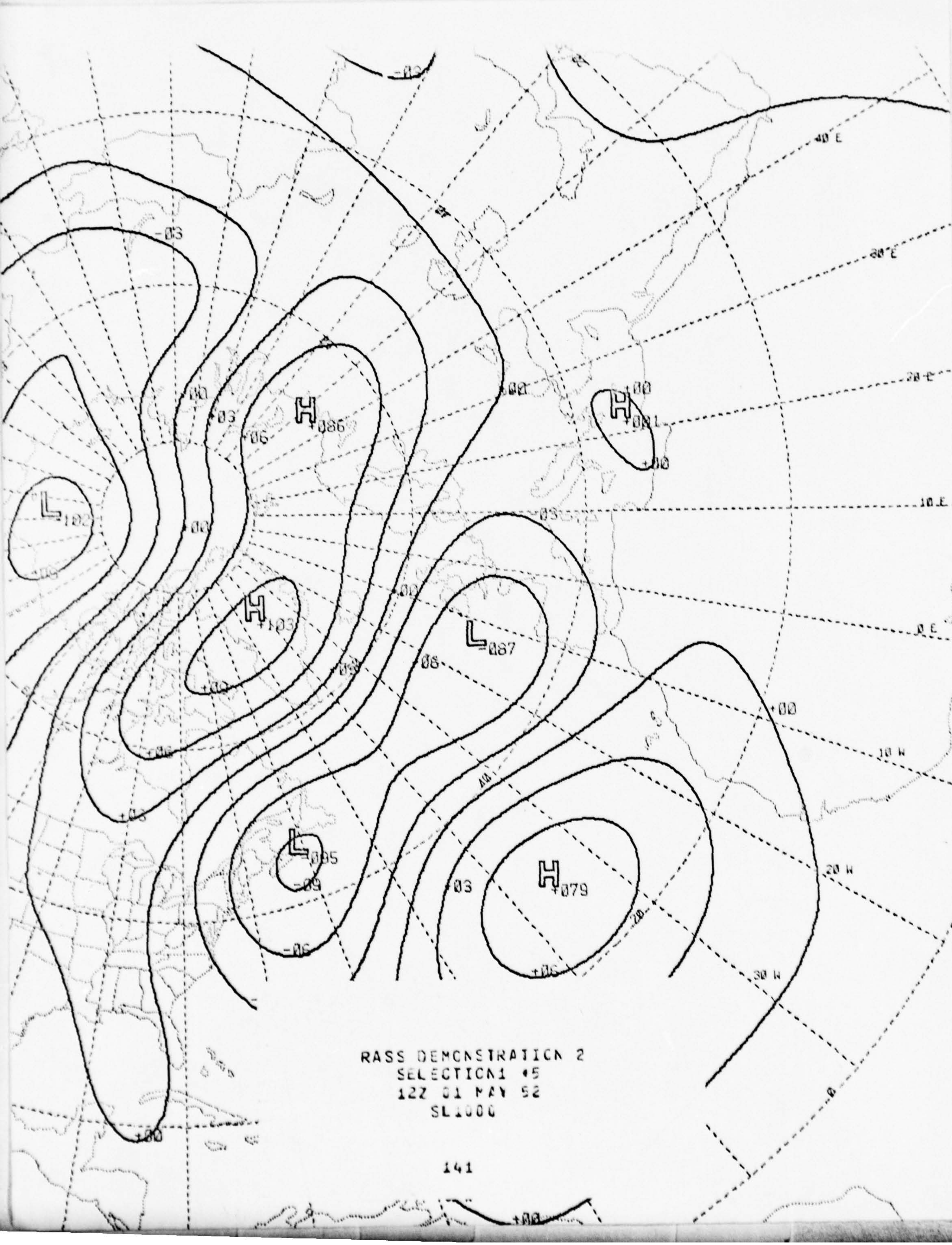
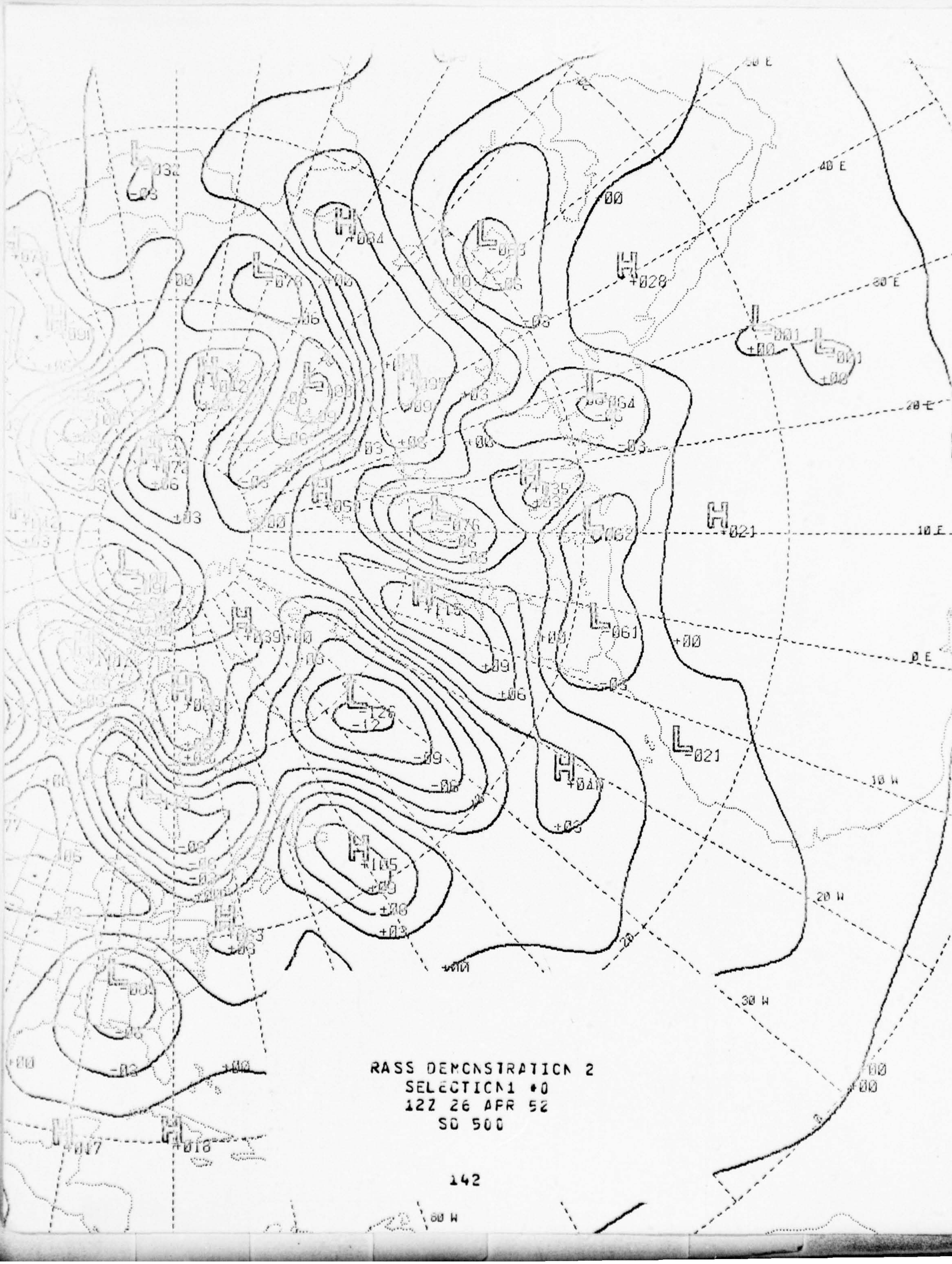
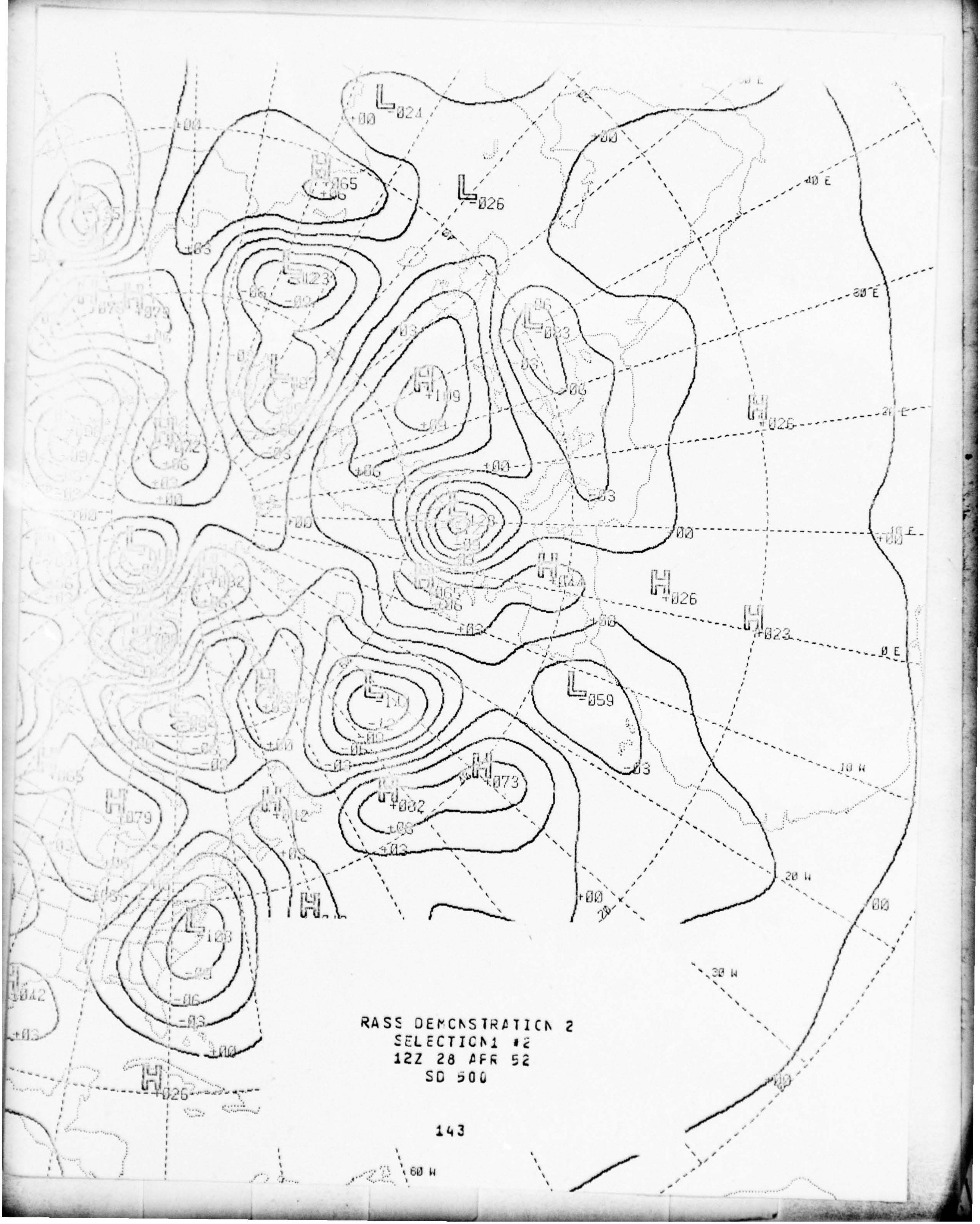
SELECTION1 #2
12Z 28 APR 52
SL1000



RASS DEMONSTRATION 2
SELECTION1 45
12Z 01 MAY 92
SL1000



RASS DEMONSTRATION 2
SELECTION1 +0
12Z 26 APR 82
SD 500



RASS DEMONSTRATION 2
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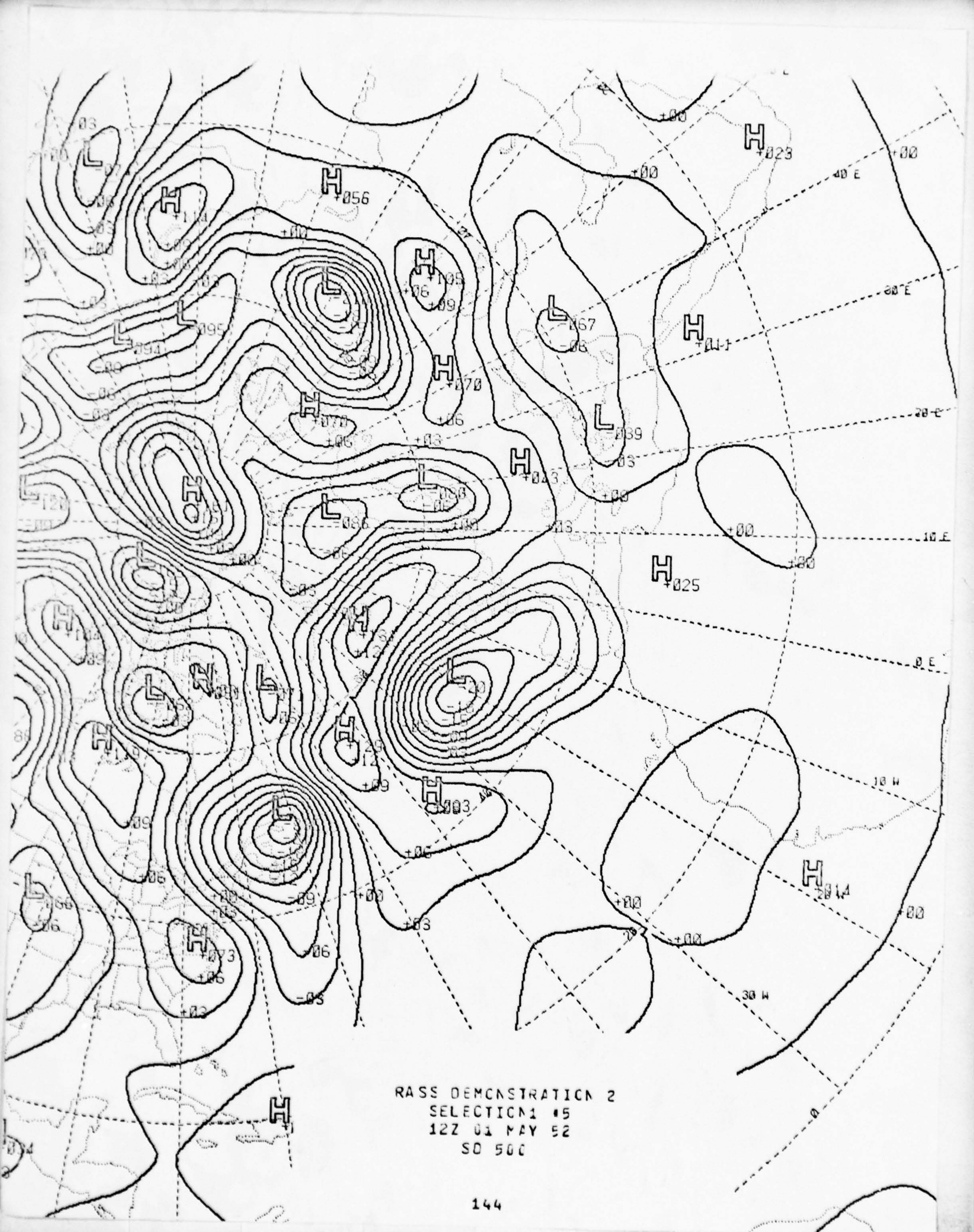
12Z 28 APR 52
SD 500



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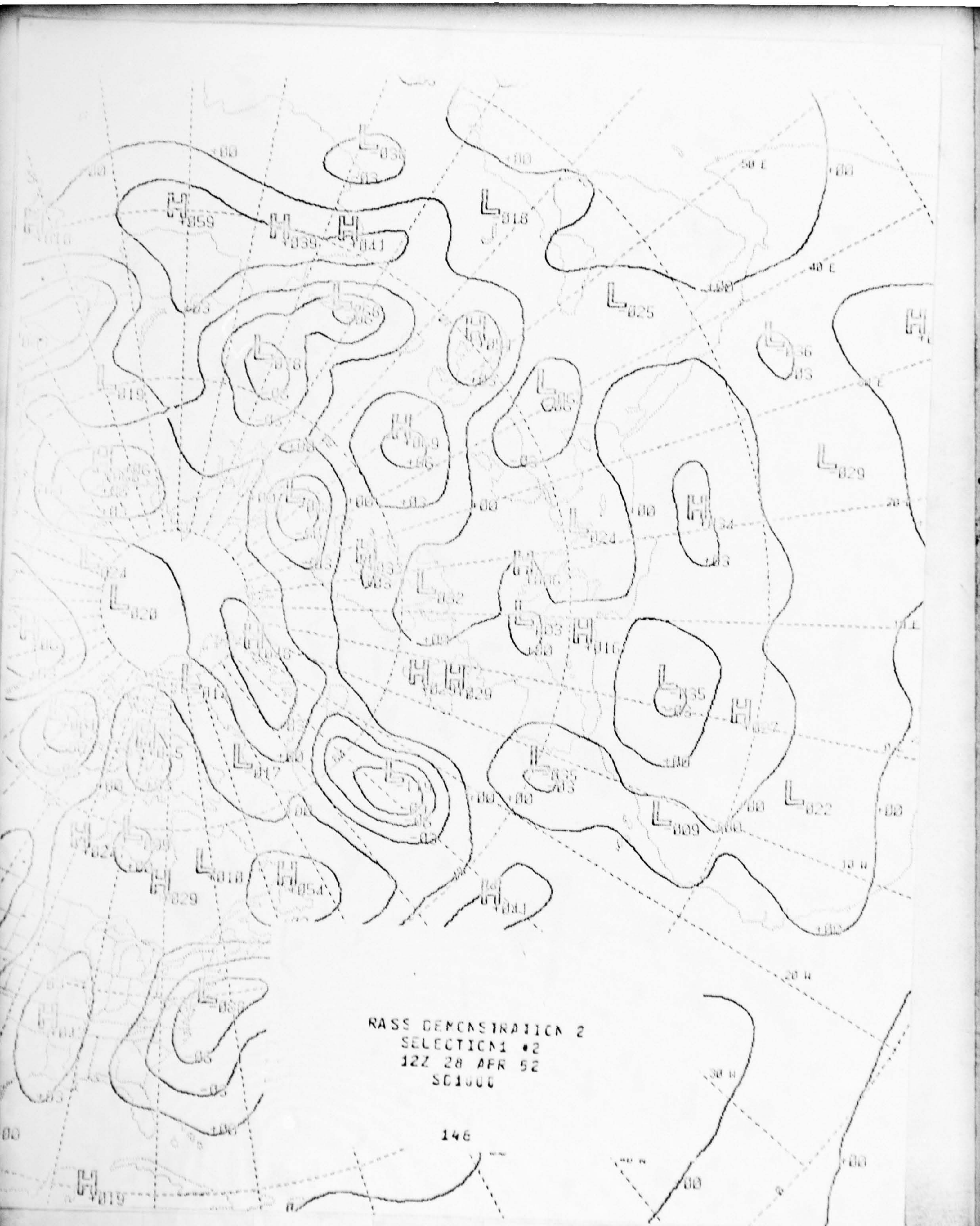
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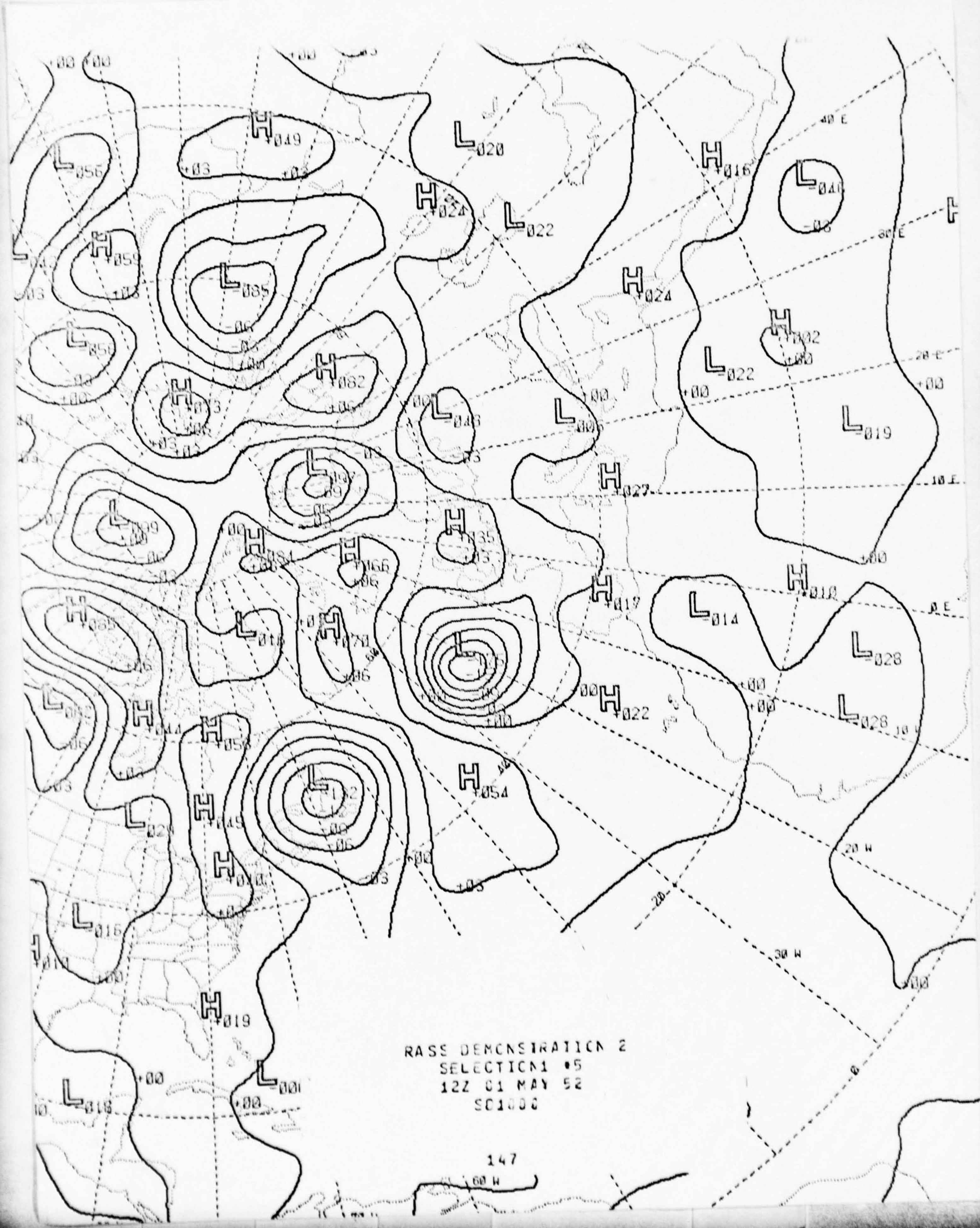
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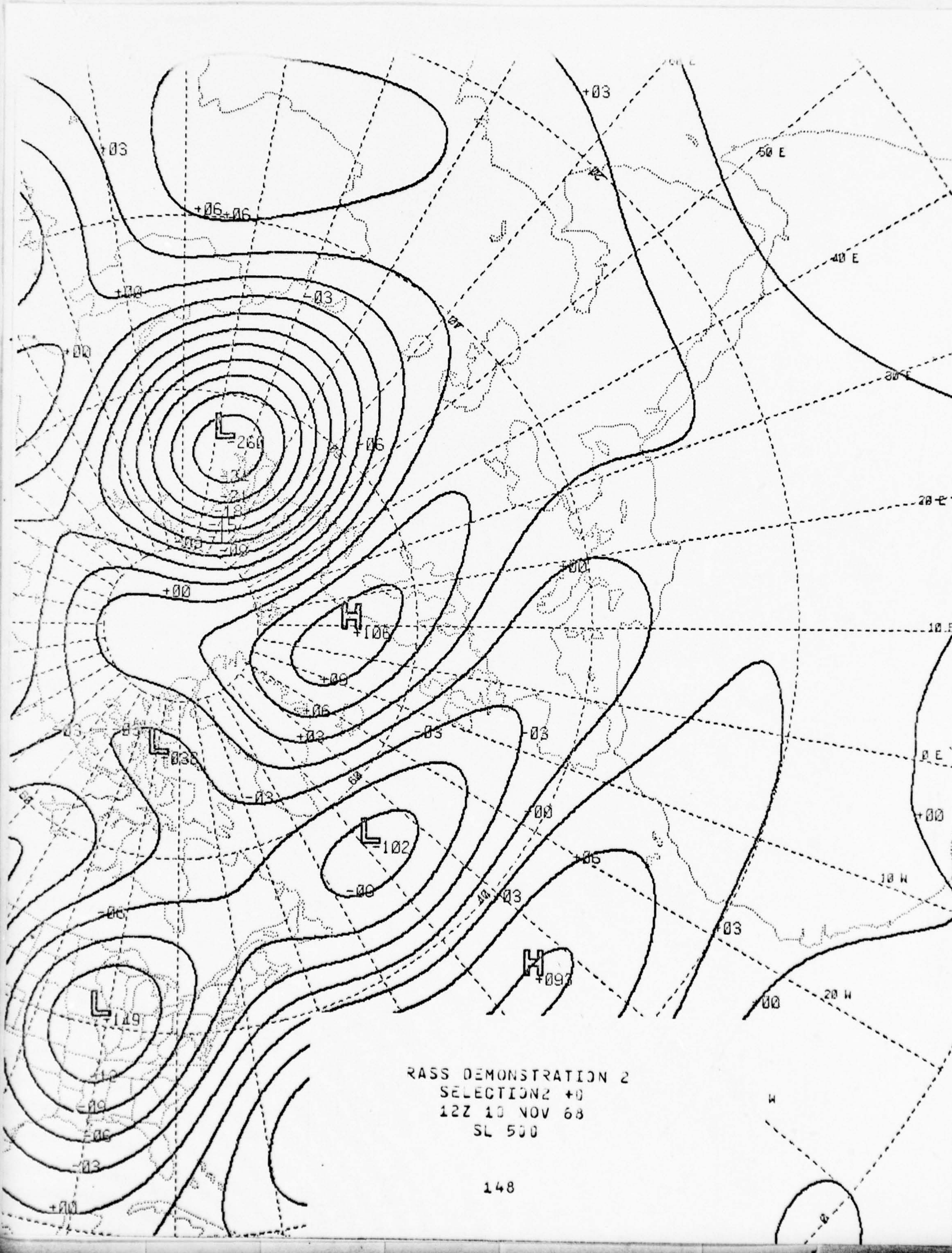

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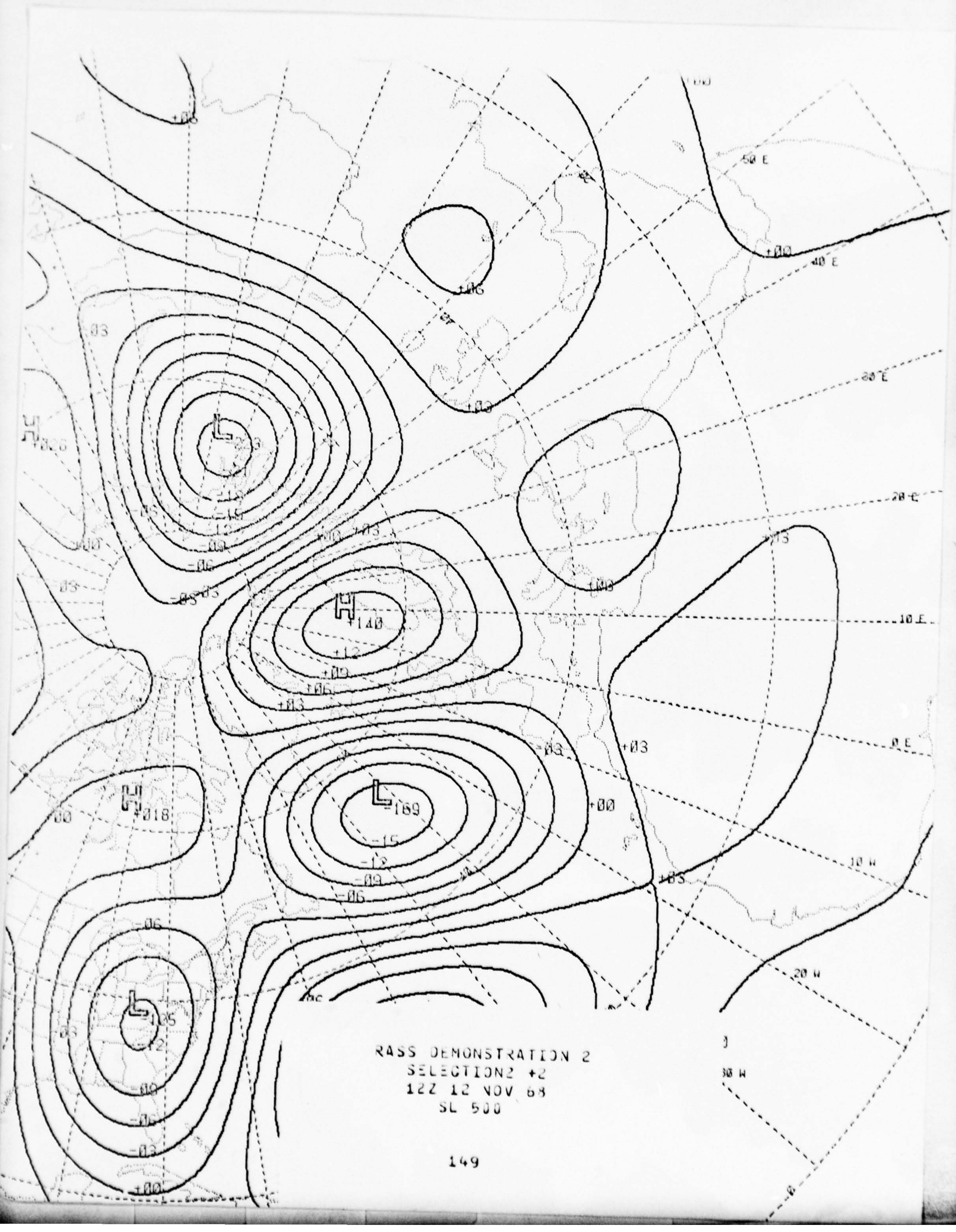
SL 500



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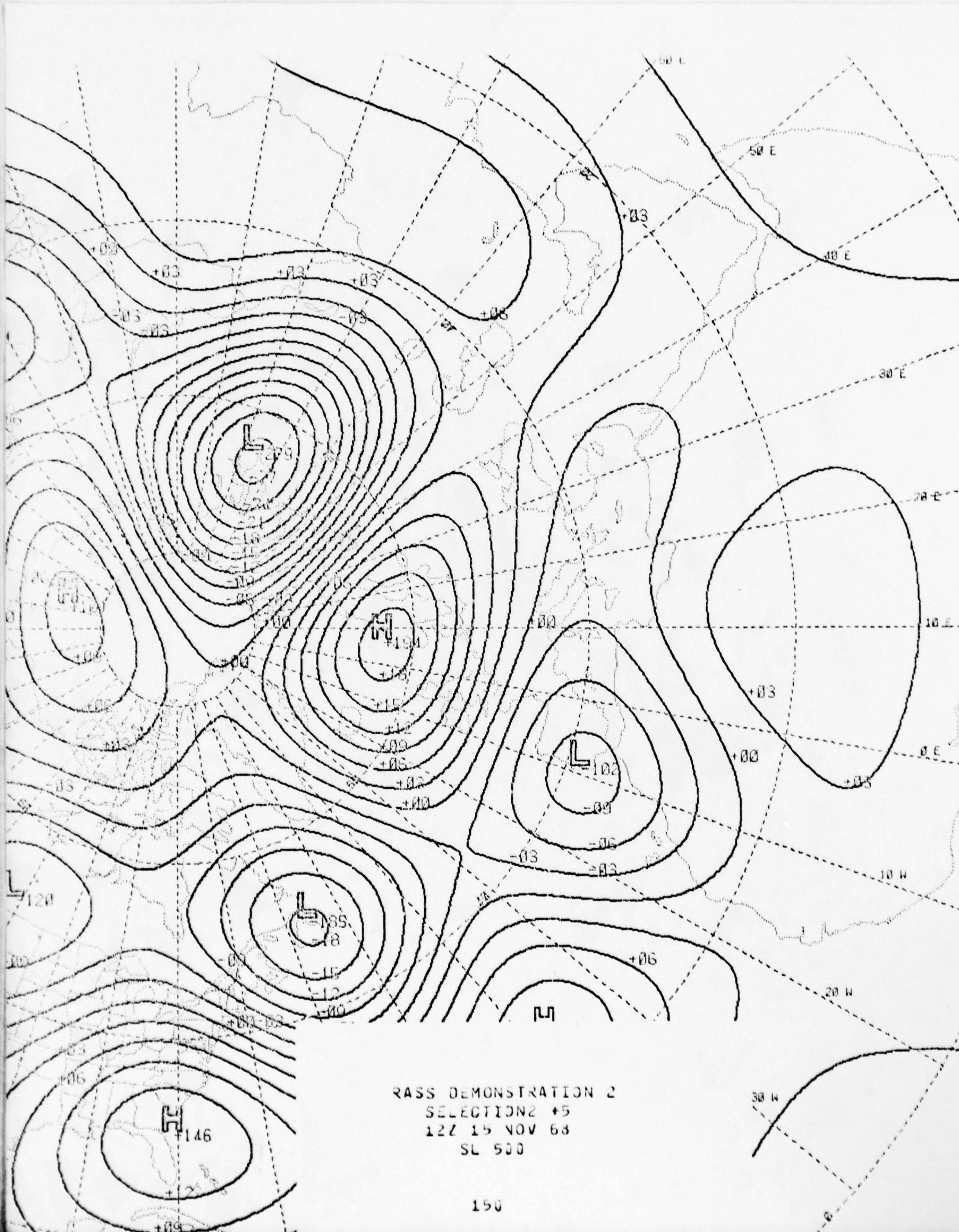
SL 500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SL 500
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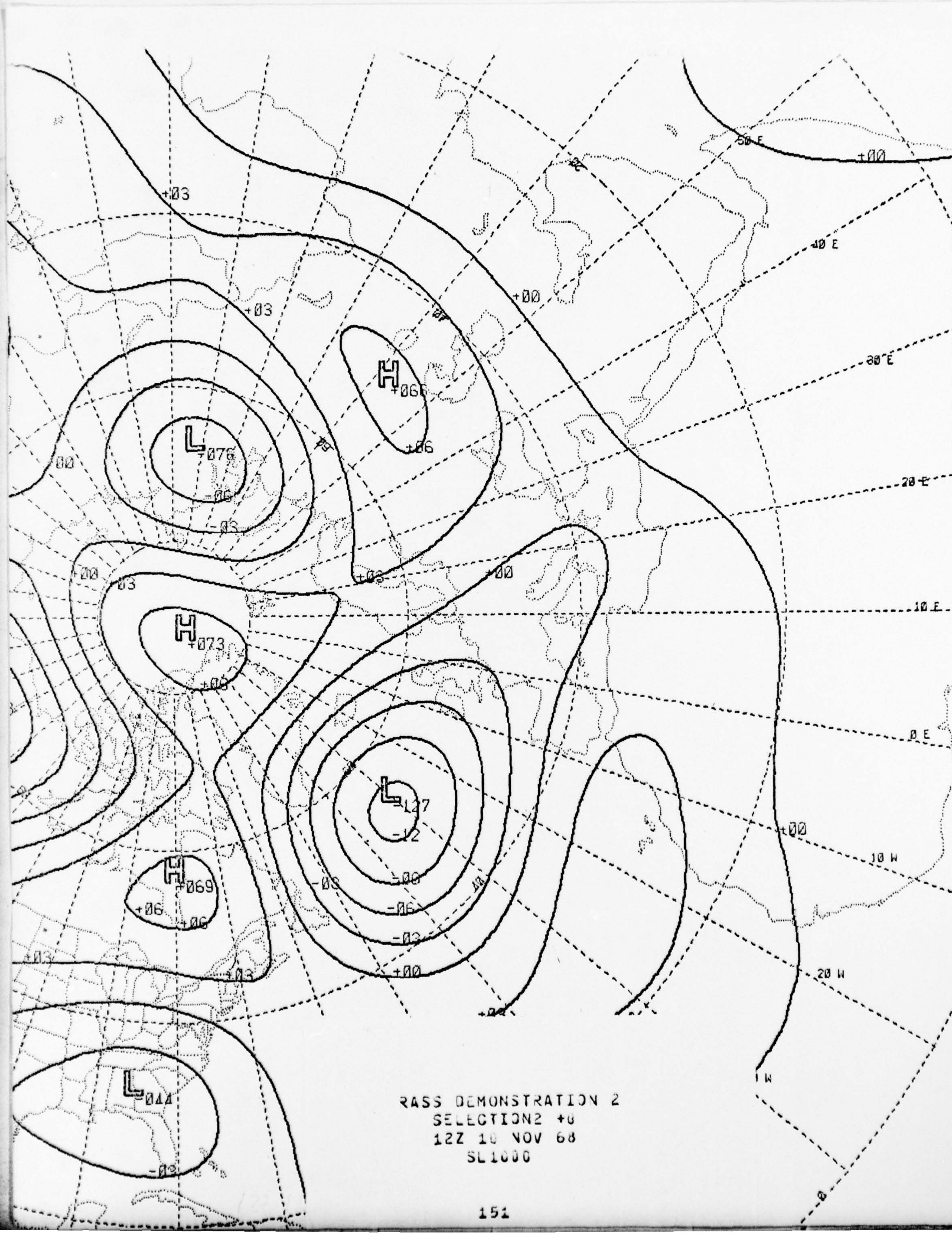
30 E
20 E
10 E
0 E
10 W
20 W
30 W



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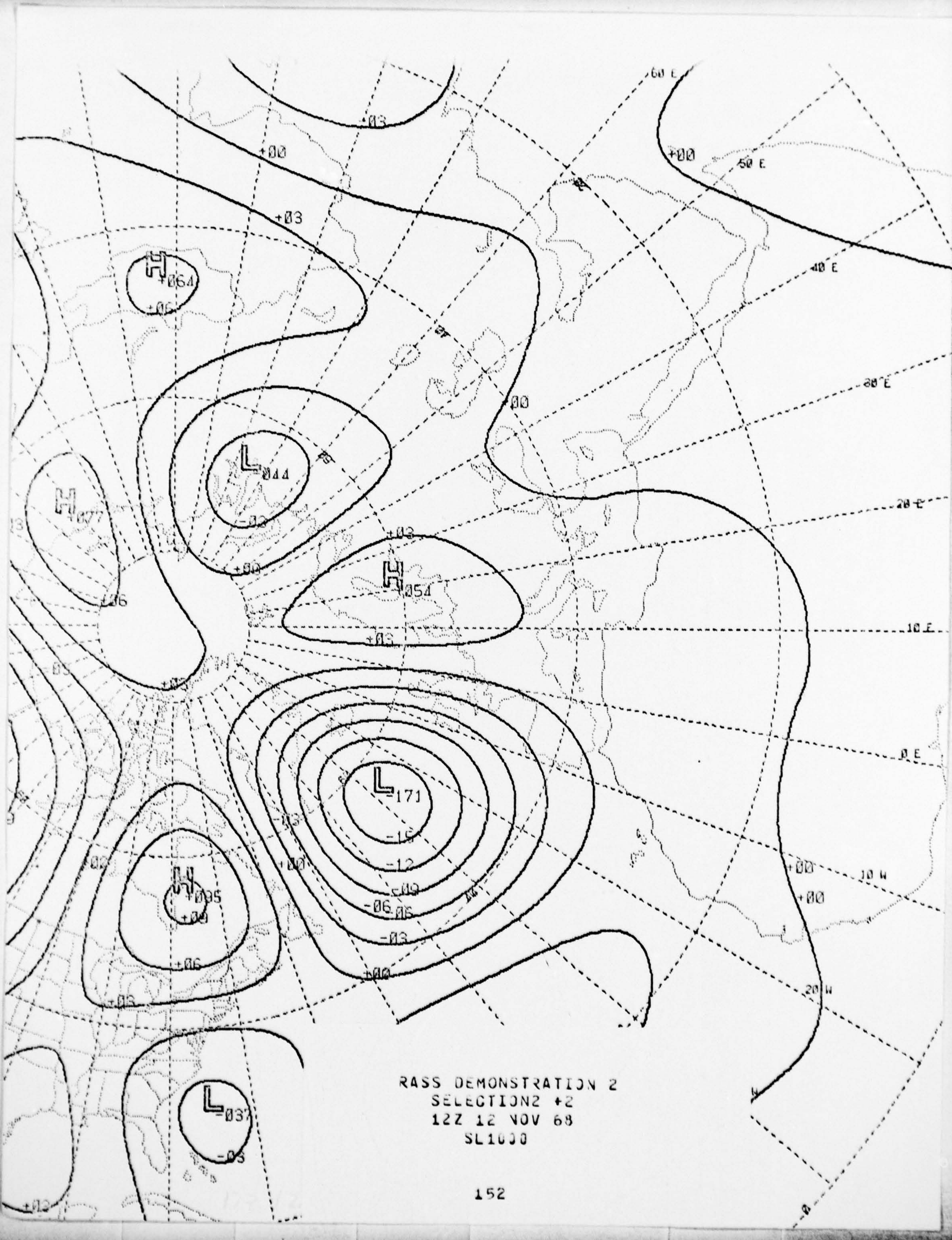

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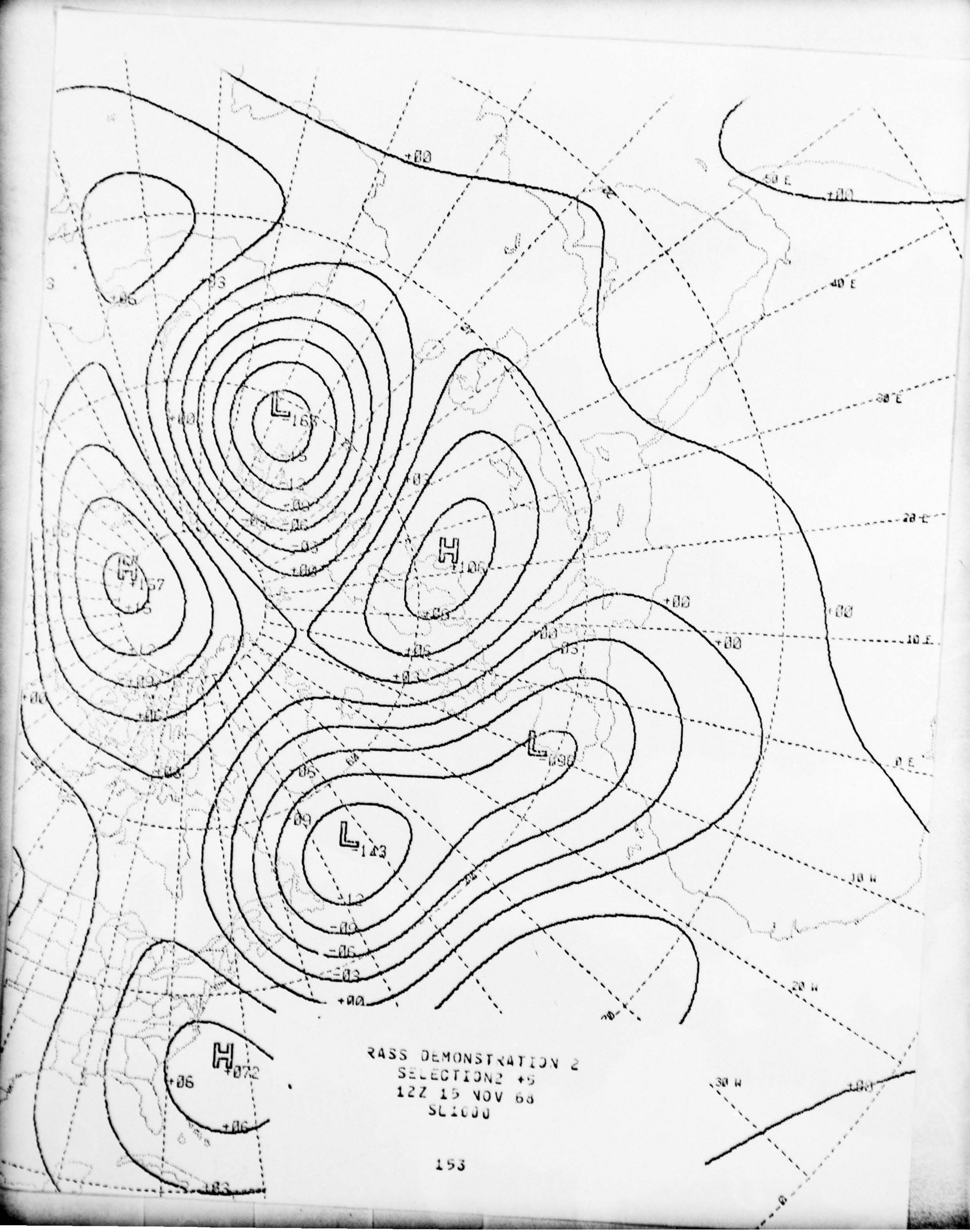

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12Z 15 NOV 68
SL1000

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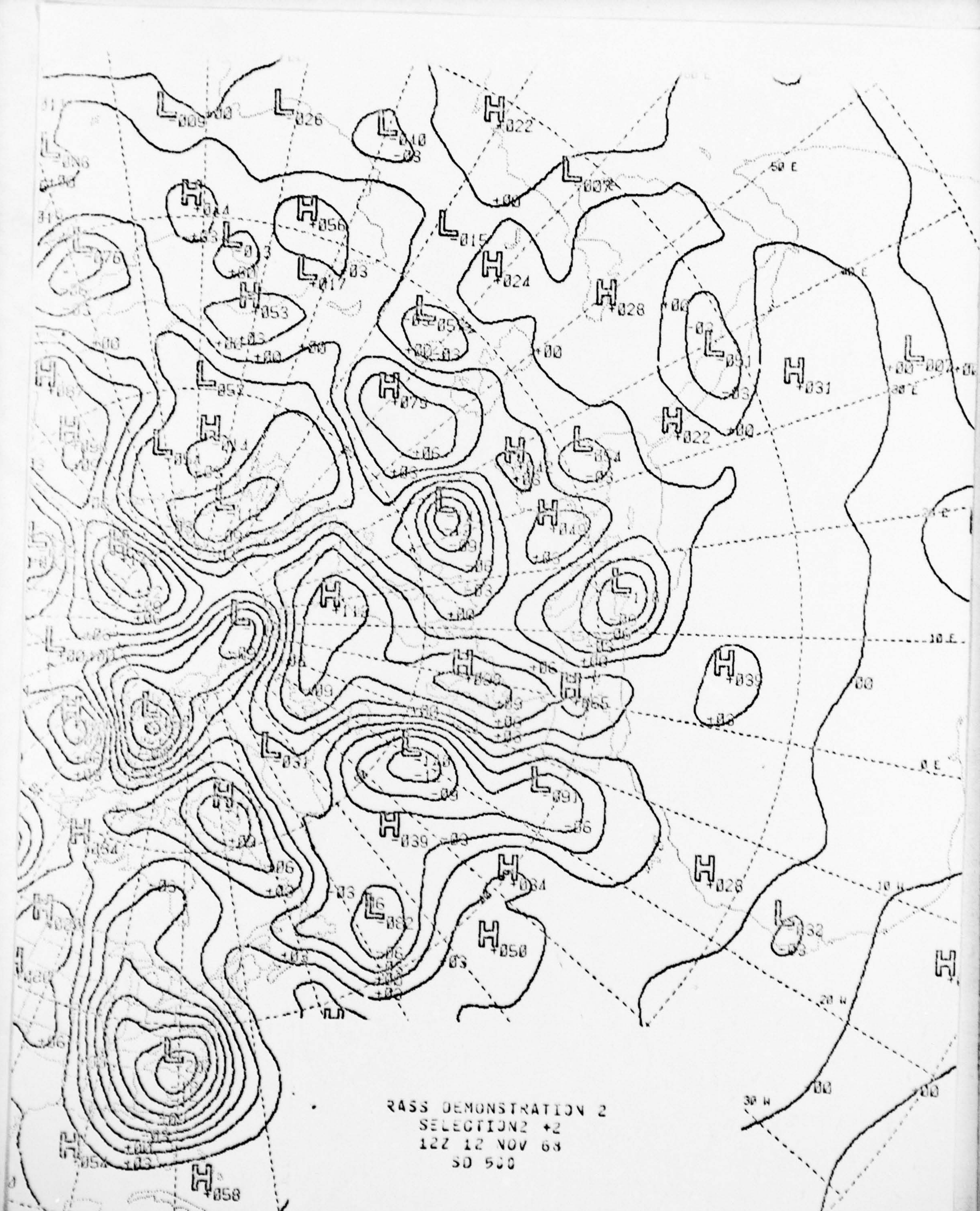

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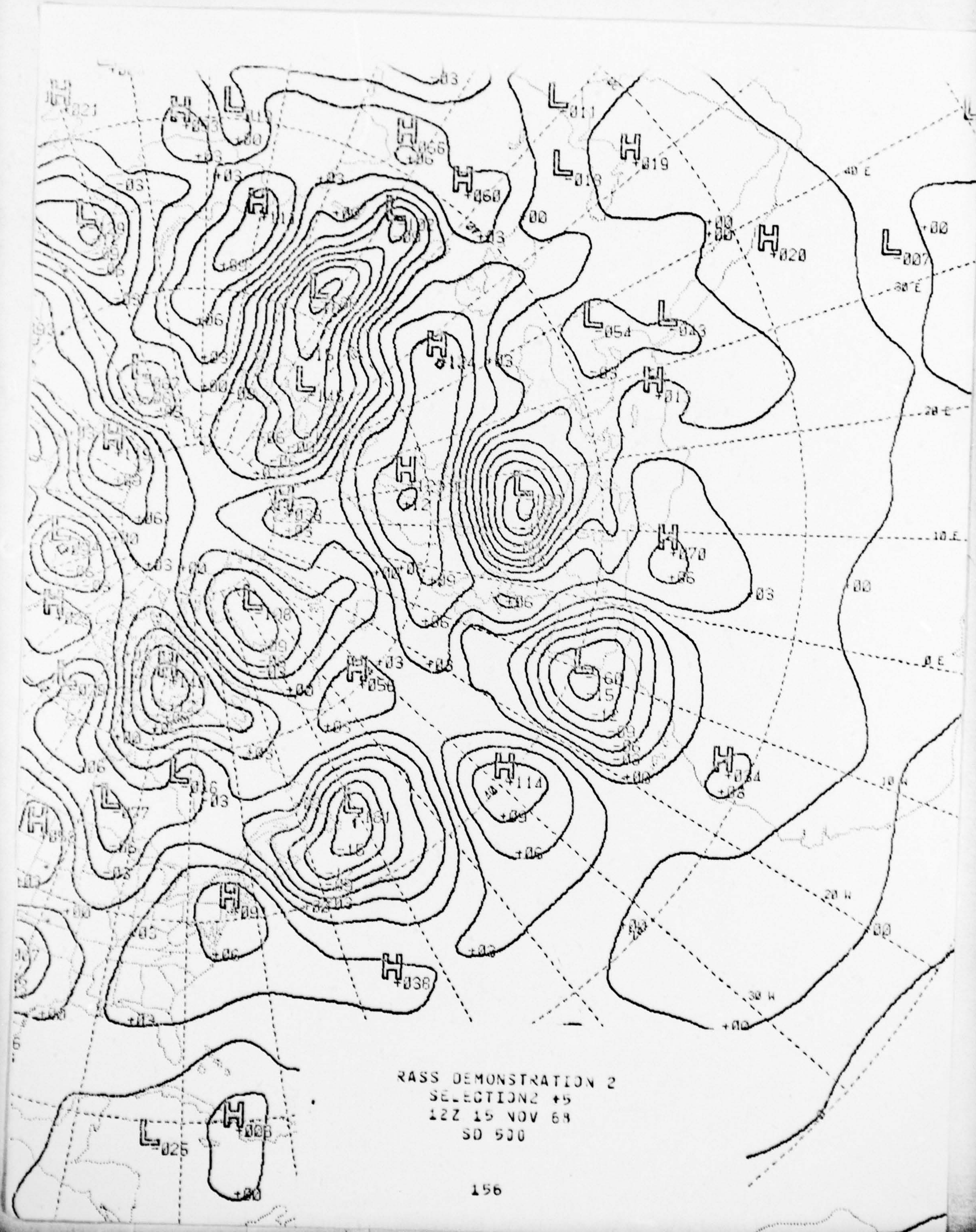

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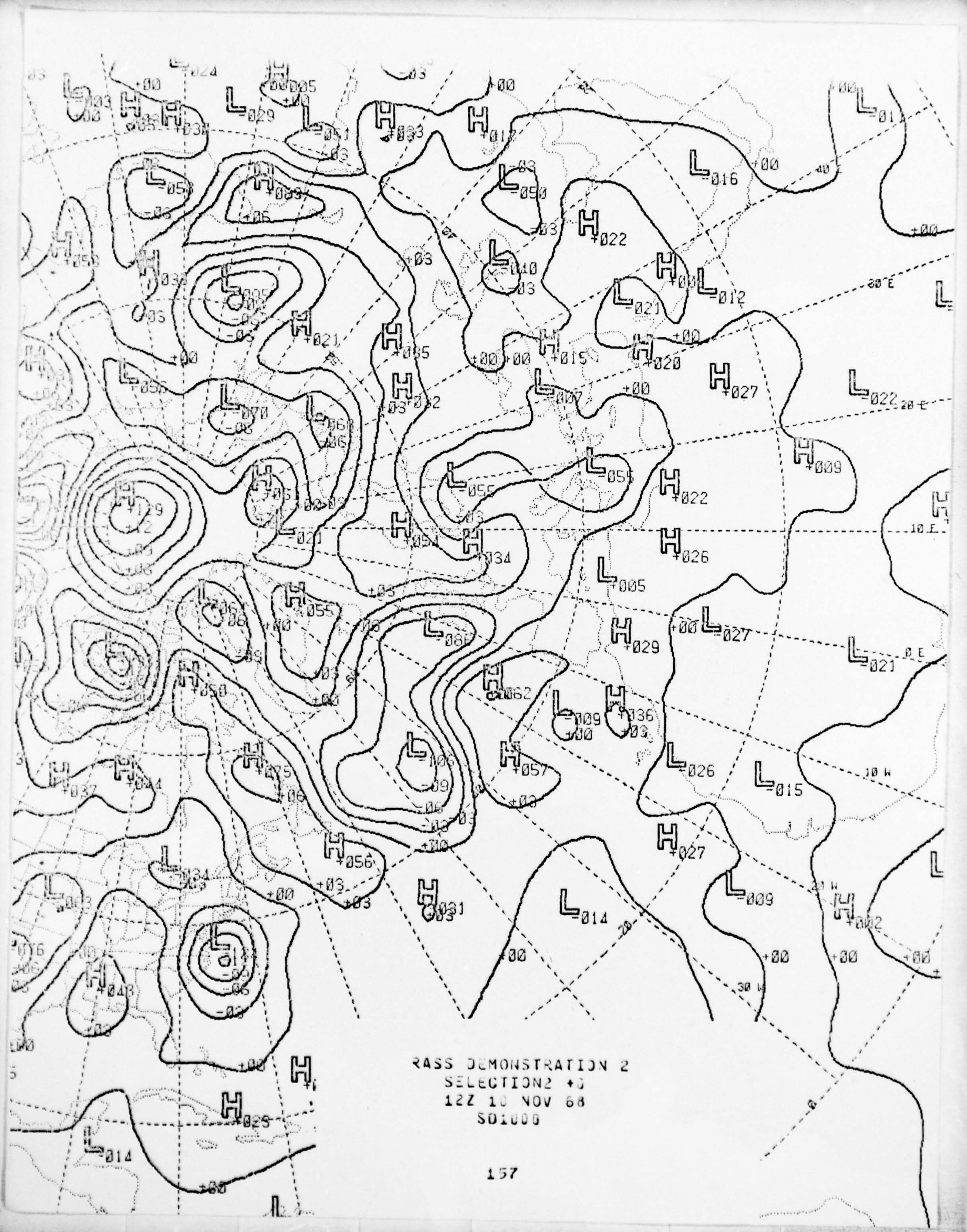
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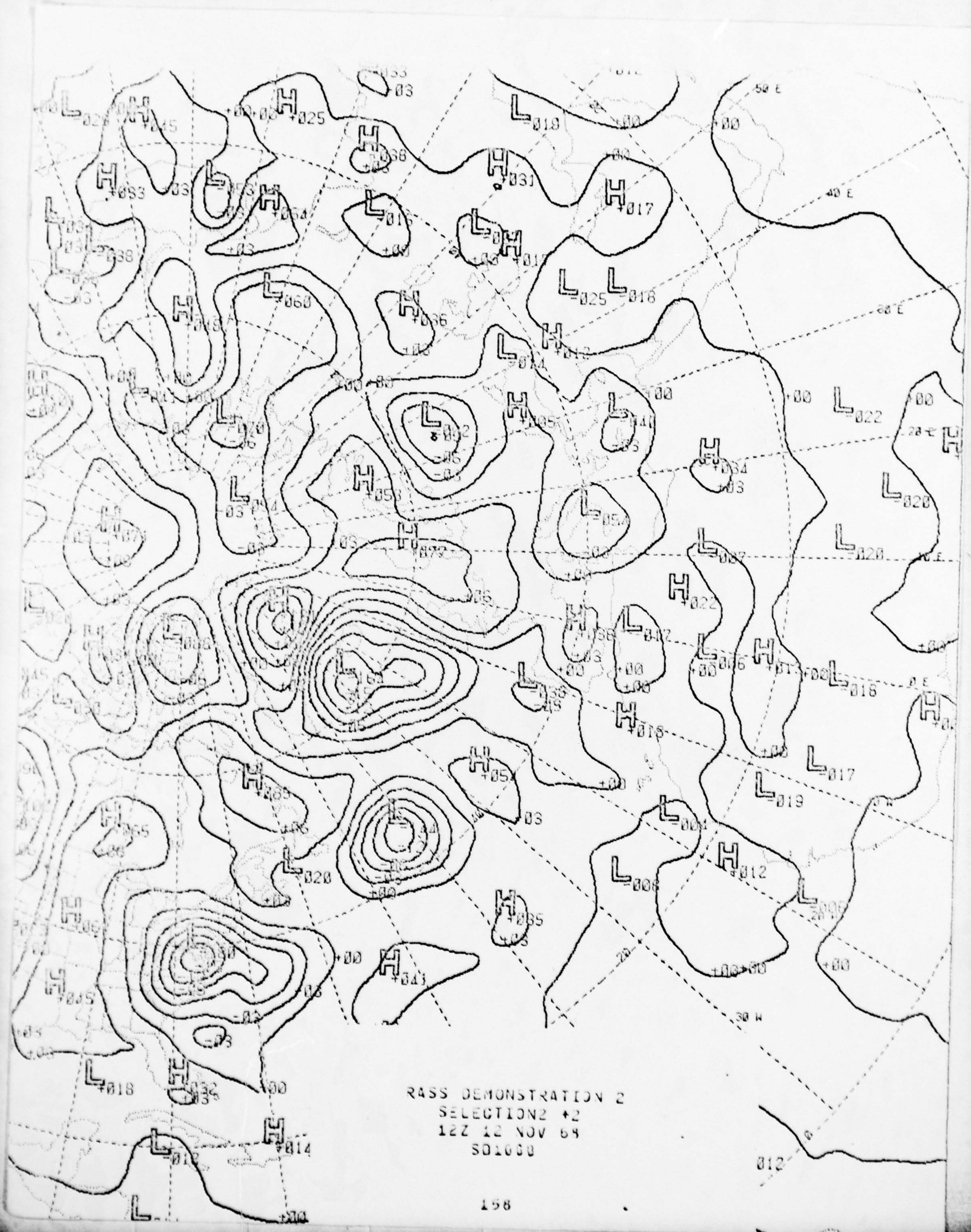

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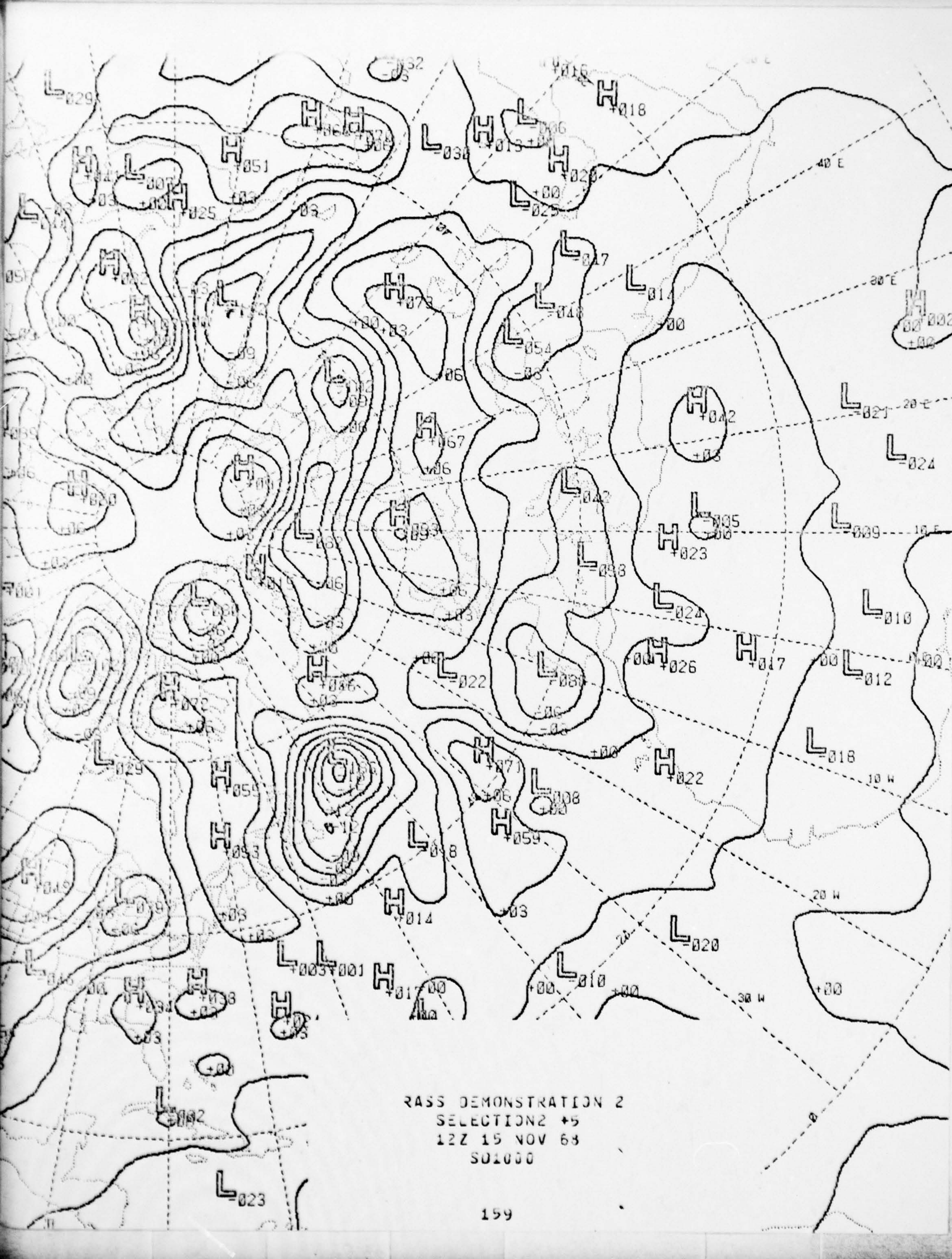

RASS DEMONSTRATION 2
SELECTION2 +5
12Z 15 NOV 68
S01000

APPENDIX A

SCALE-AND-PATTERN SPECTRA AND DECOMPOSITIONS

Two of the fundamental concepts in the interpretation of meteorological fields are those of pattern and scale. In 1963, MII developed an objective technique[1] for separating any geophysical field into recognizable characteristic patterns, or features, evident in the field, so that their relative contributions to the total can be quantitatively represented.

Using the 500-mb height field (HT) as an example, this may be decomposed into additive component ranges-of-scale expressed by:

$$HT = SD + SR$$

$$= SD + SL + SV$$

where SD is the Disturbance range-of-scale component

SR is the Residual range-of-scale component

SL is the Long-wave range-of-scale component

SV is the Planetary Vortex .

By definition, SR = SL + SV .

Figure A1 shows the 500-mb height analysis for 12Z on 21 OCT 64. Decomposing this field into its inherent ranges-of-scale yields the SV field shown in Fig. A2, the SL field shown in Fig. A3 and the SD field shown in Fig. A4.

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[1] Manfred M. Holl, Scale-and-pattern spectra and decompositions, Technical Memorandum No. 3, Contract N228-(62271)60550, Meteorology International Incorporated, Monterey, California, 1963.

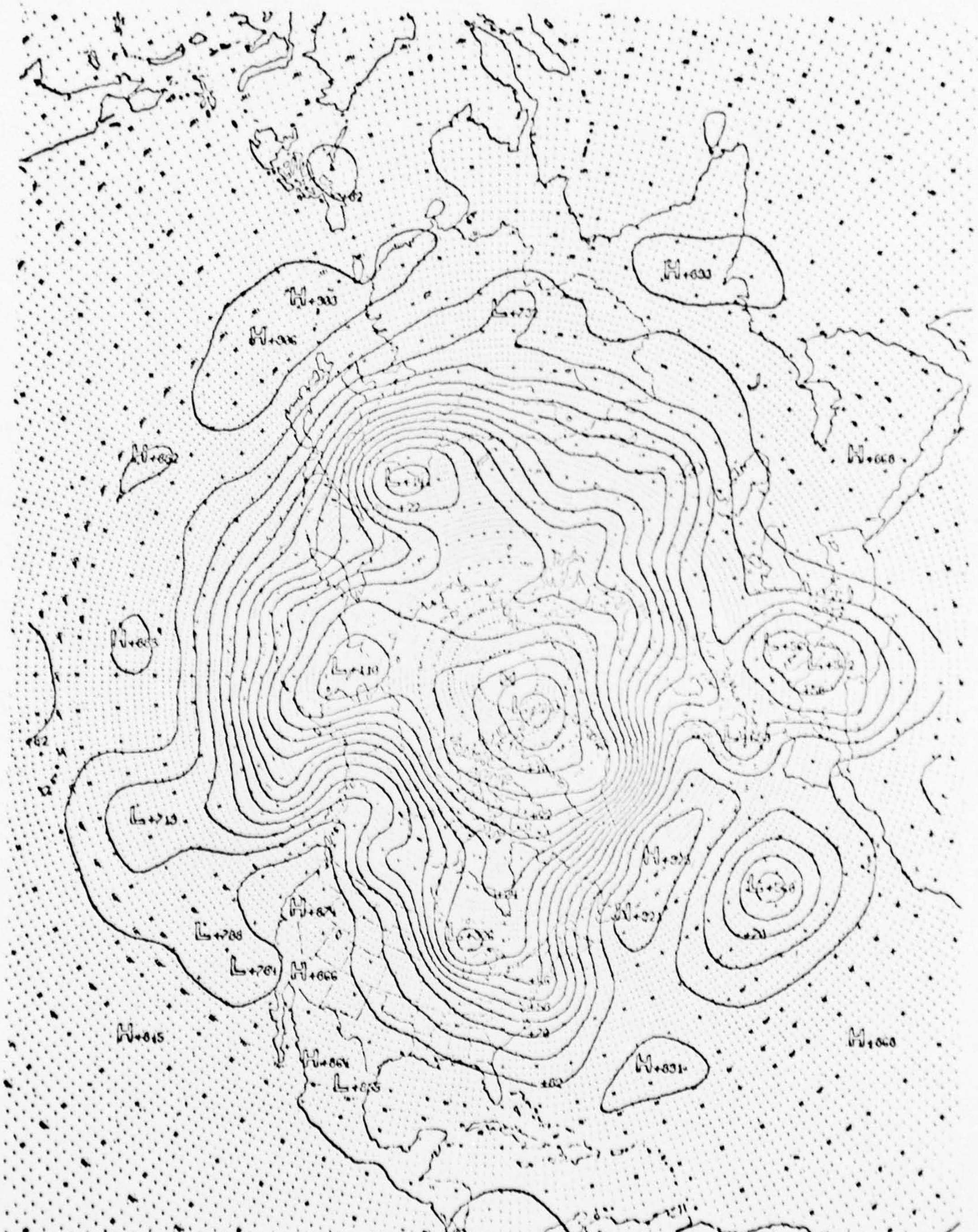

Fig. A1

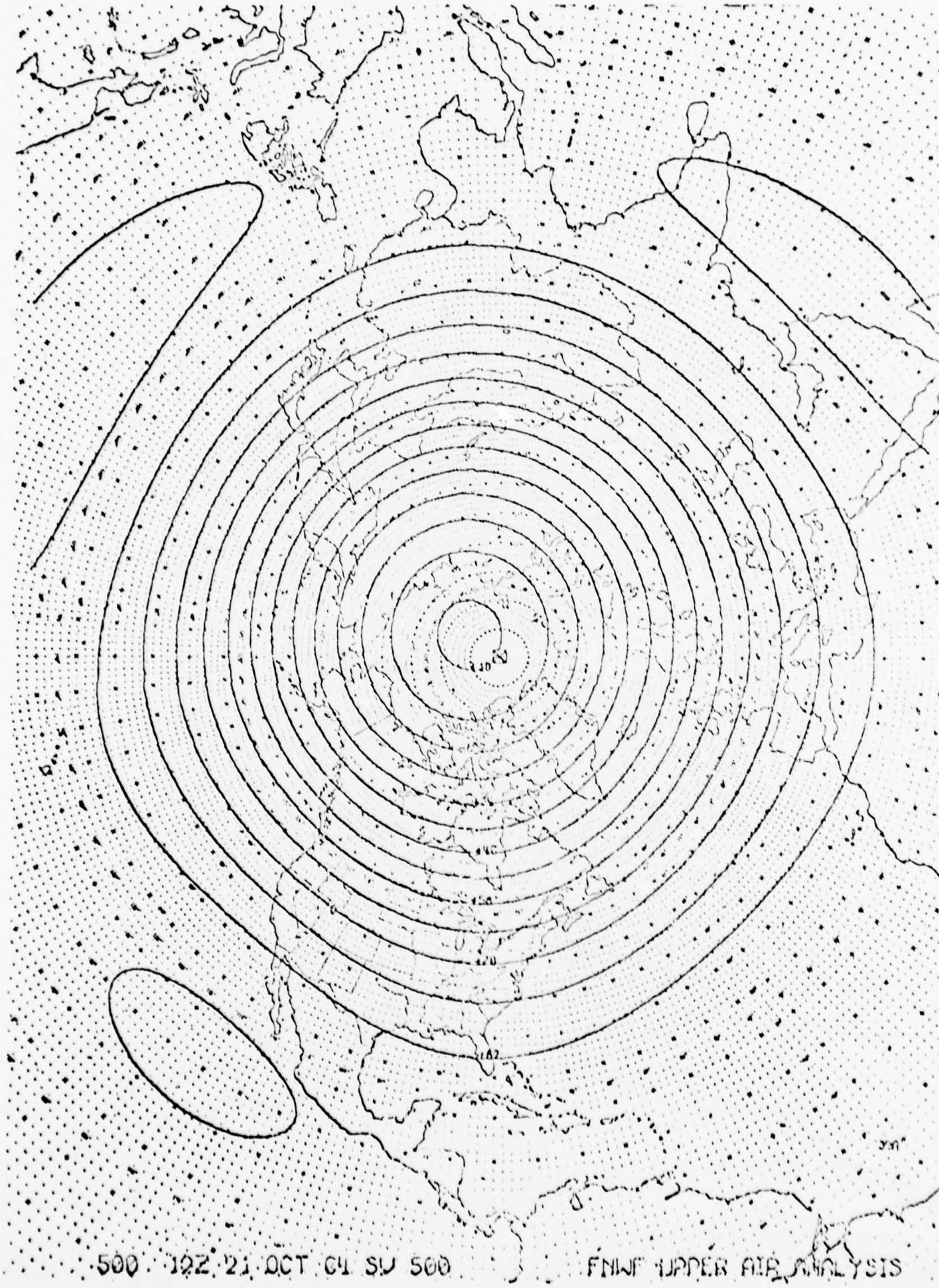

Fig. A2

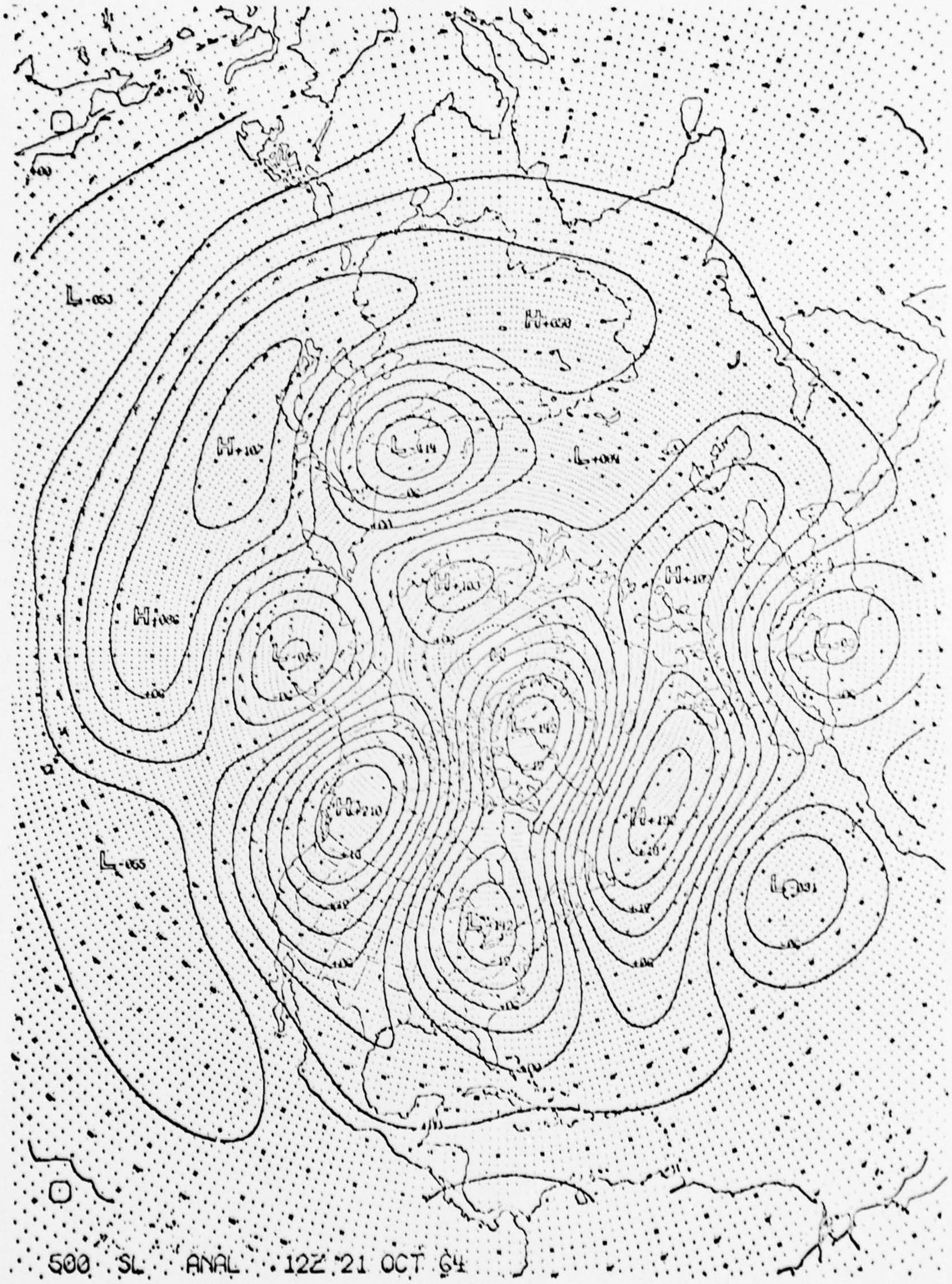

Fig. A3

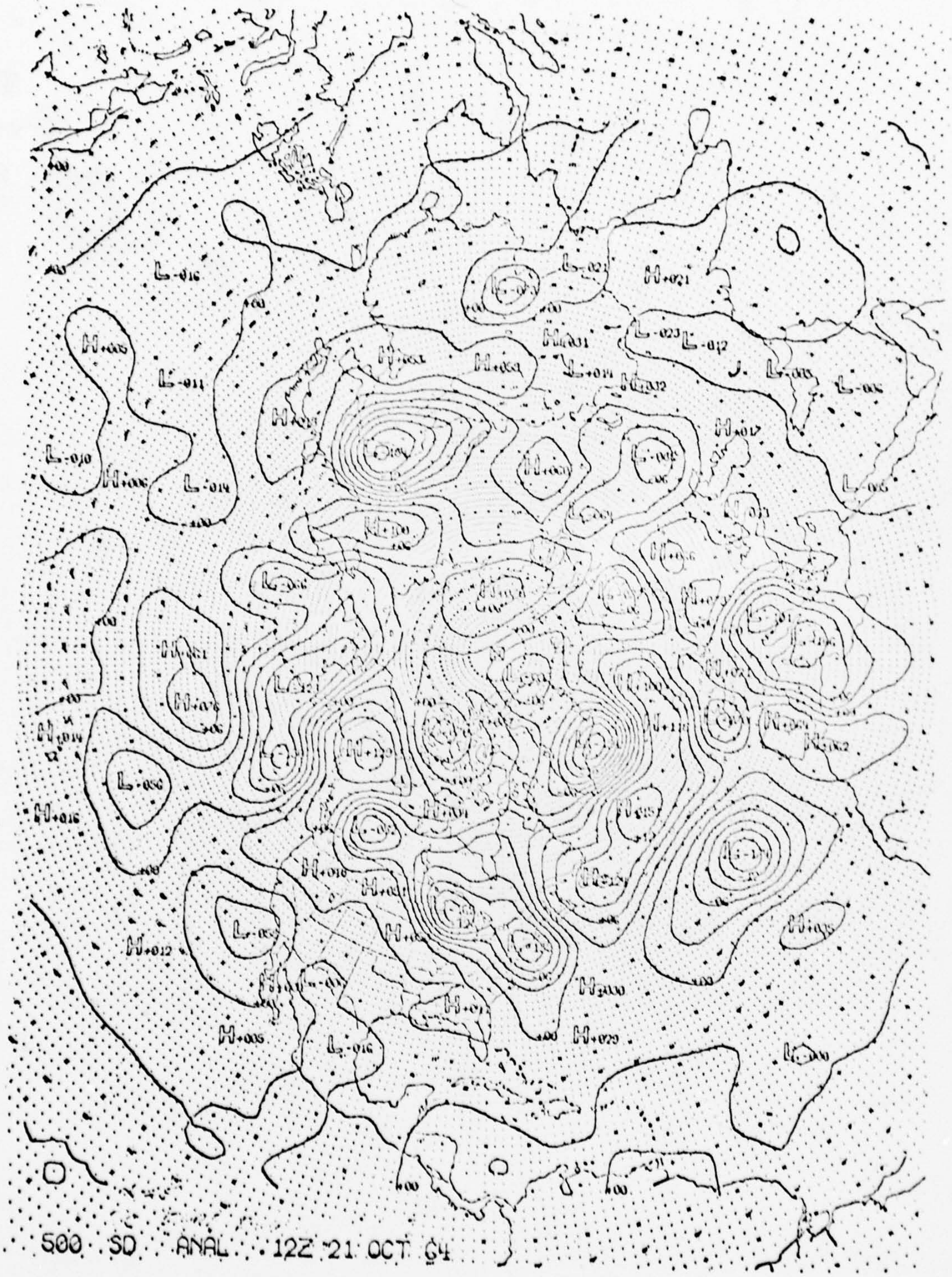

Fig. A4